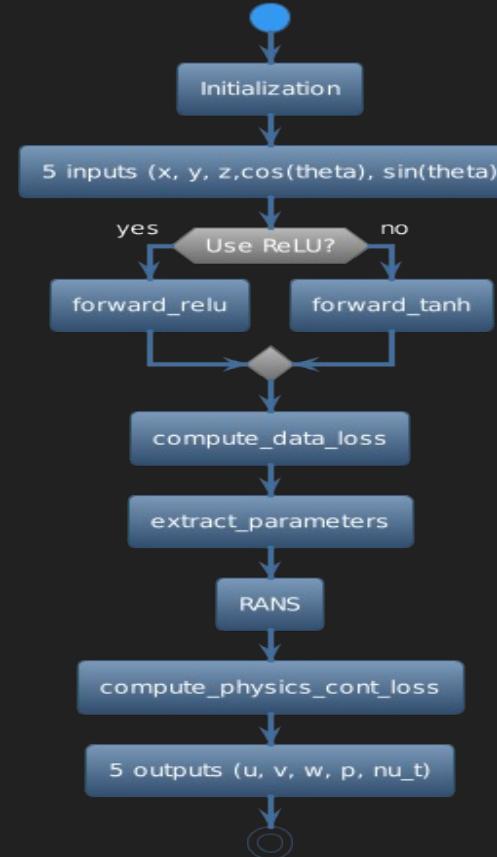
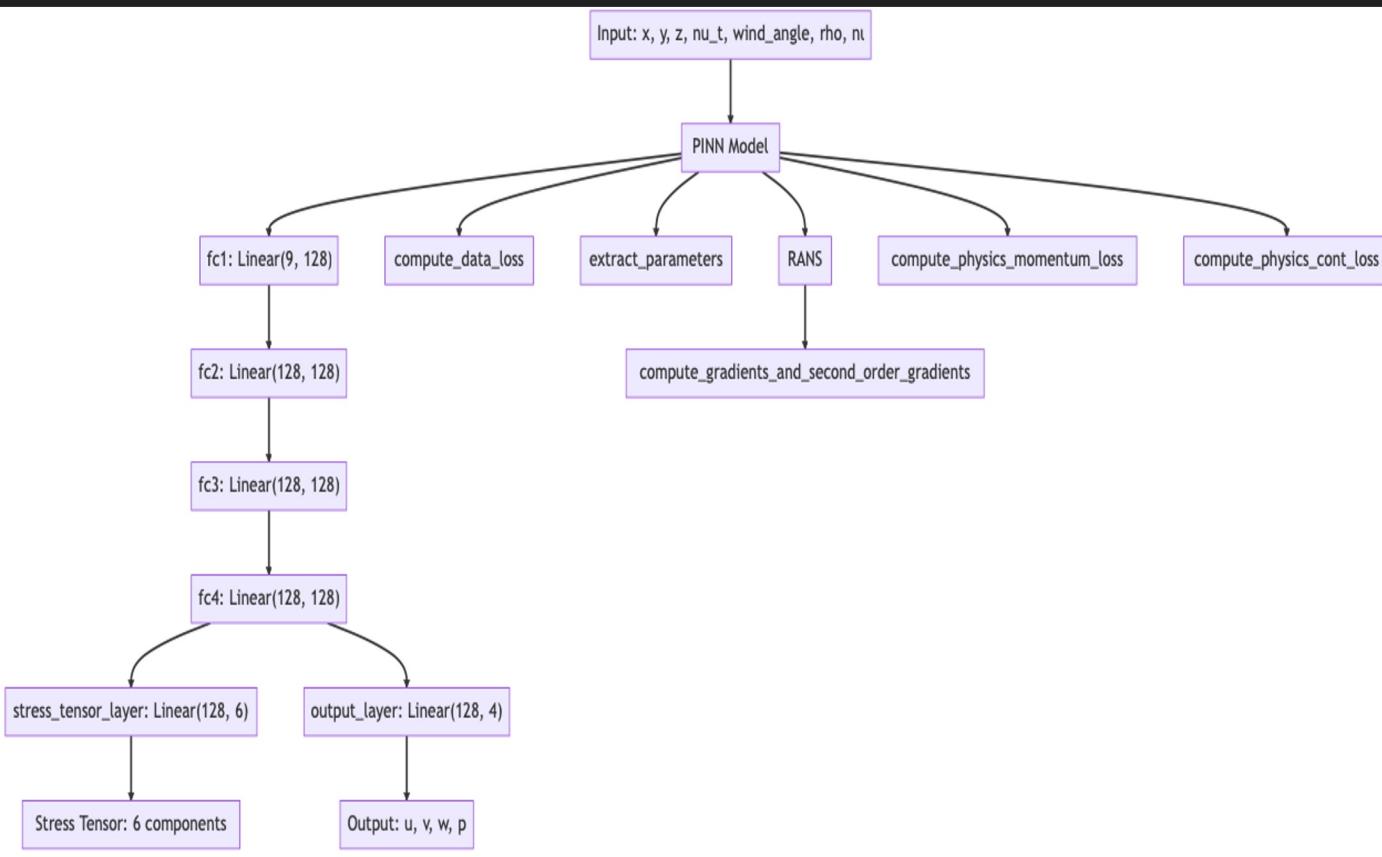


PM004 – 06 November 2023

Update on PINNs

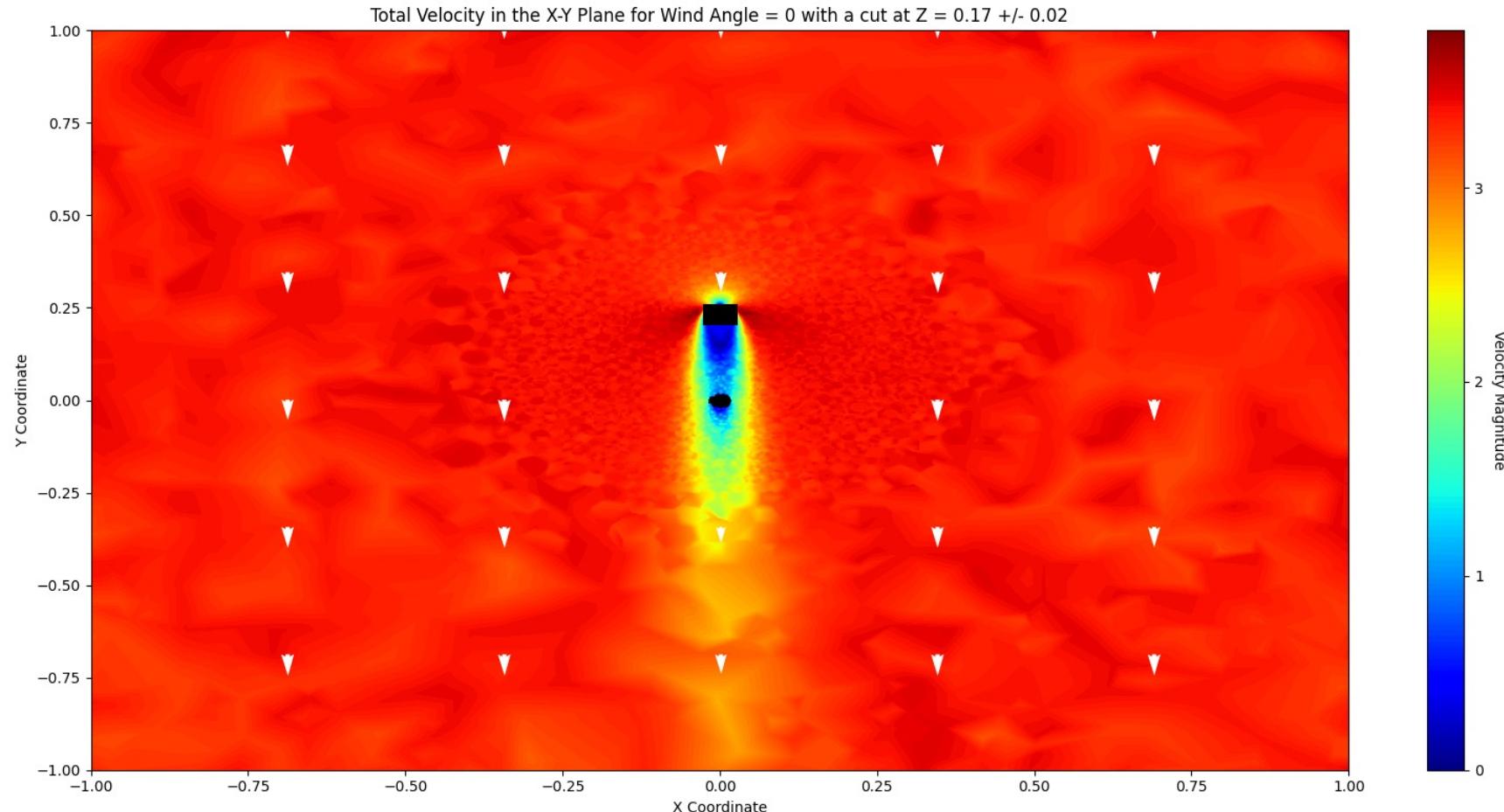
Application to Urban Wind Field Dispersion Studies

Neural Network Architecture – Previous vs Updated

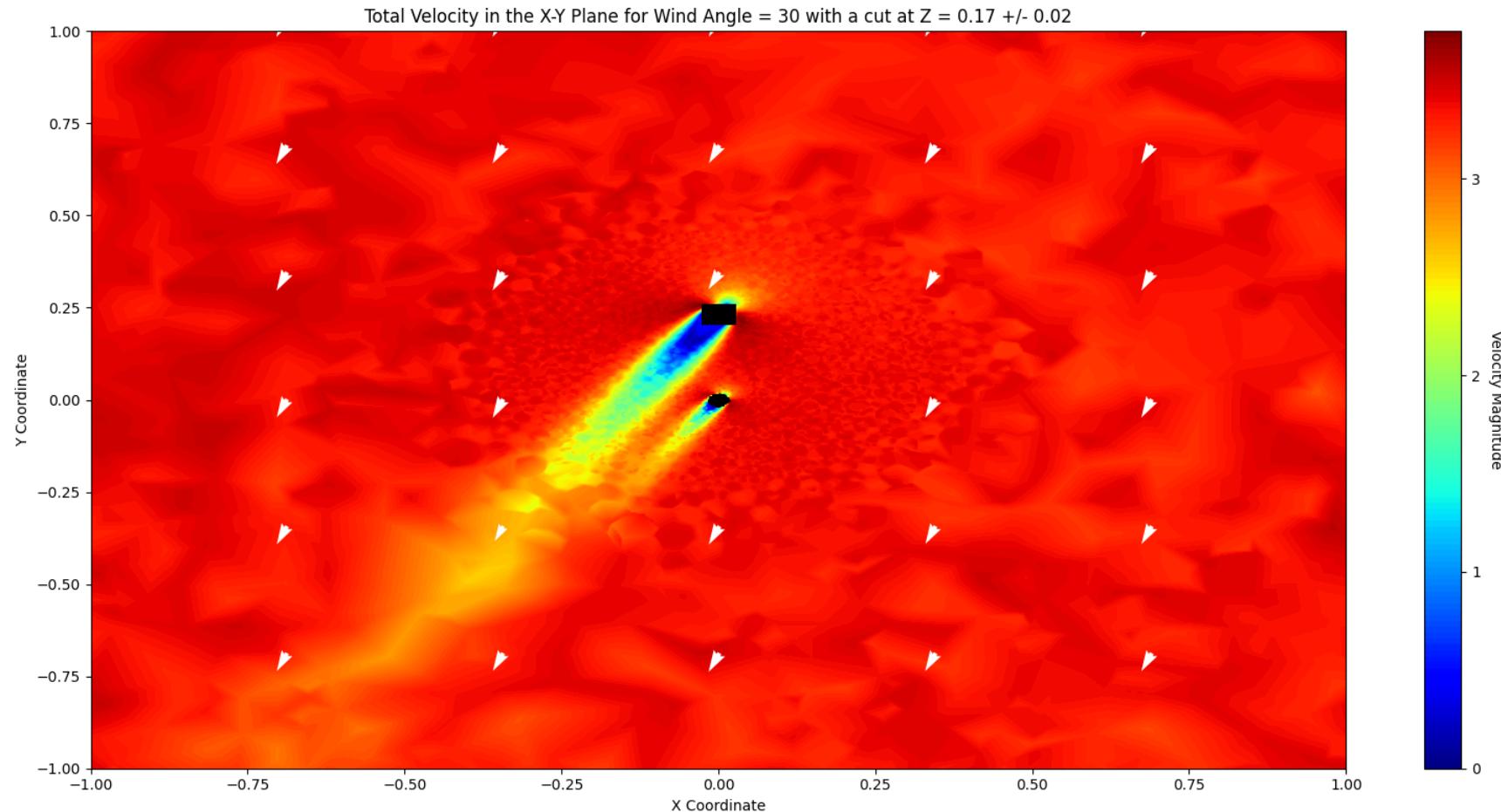


Pure Data Plots (with arrows)

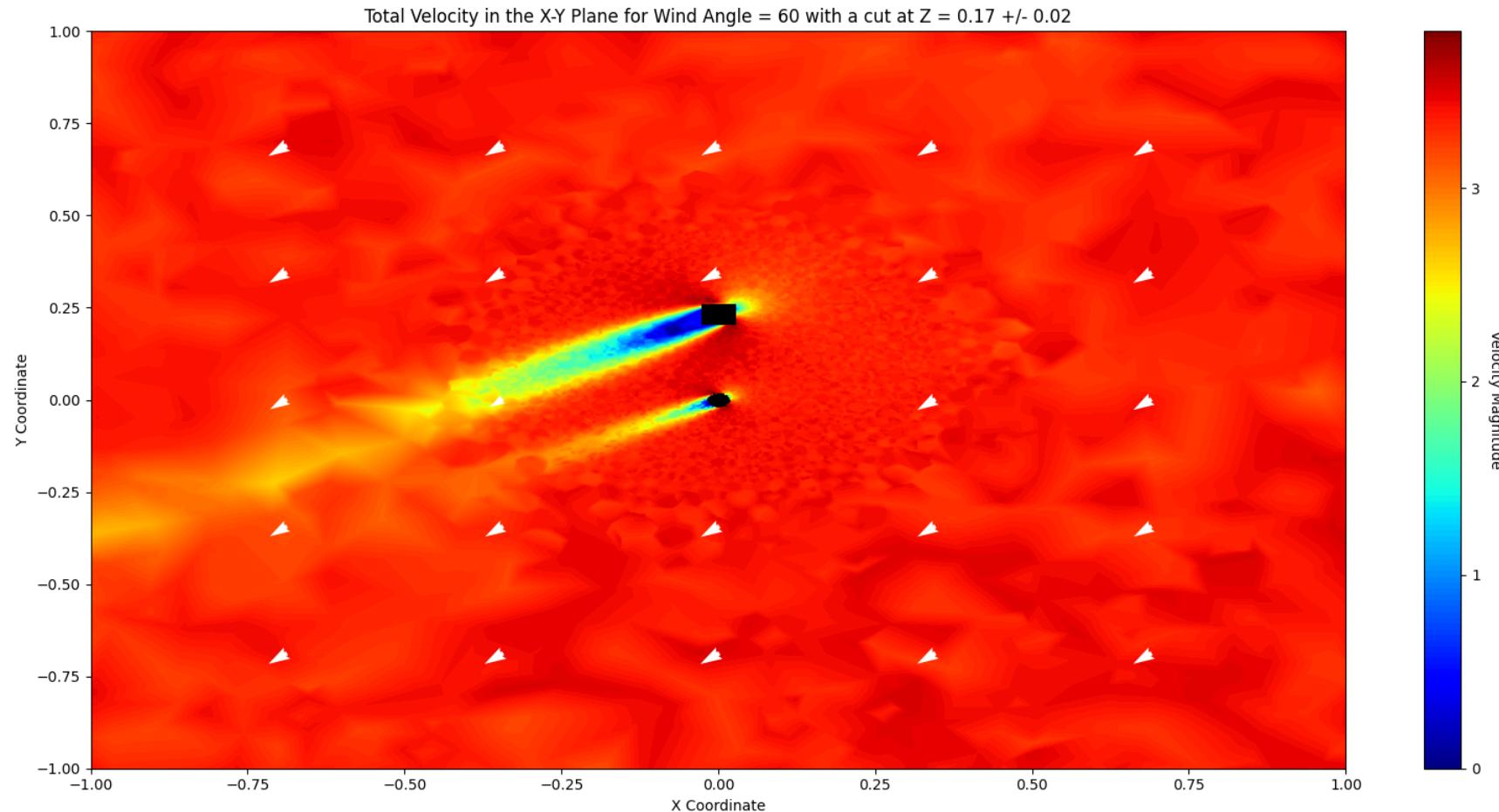
Data Plots – wind angle = 0



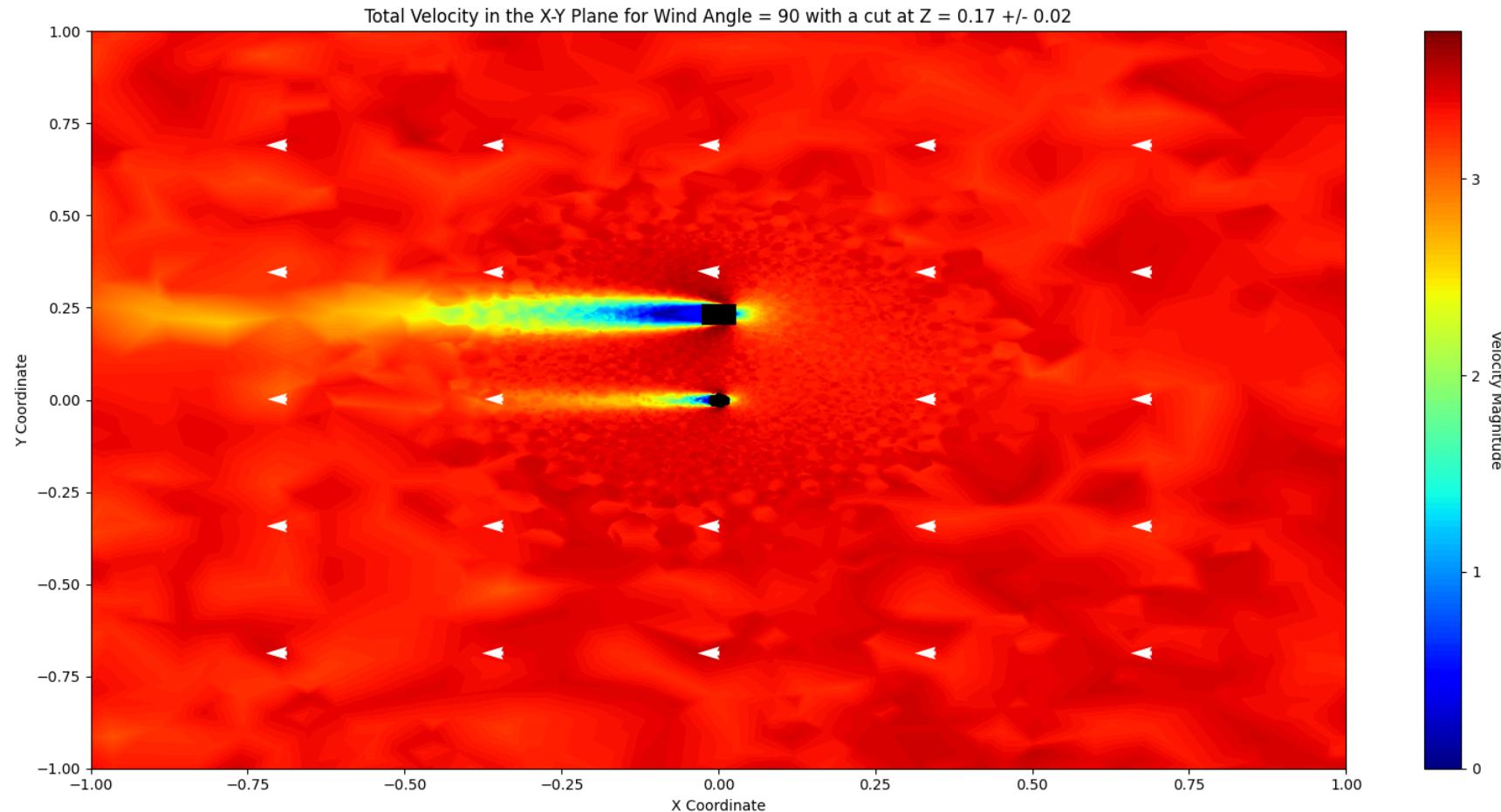
Data Plots – wind angle = 30



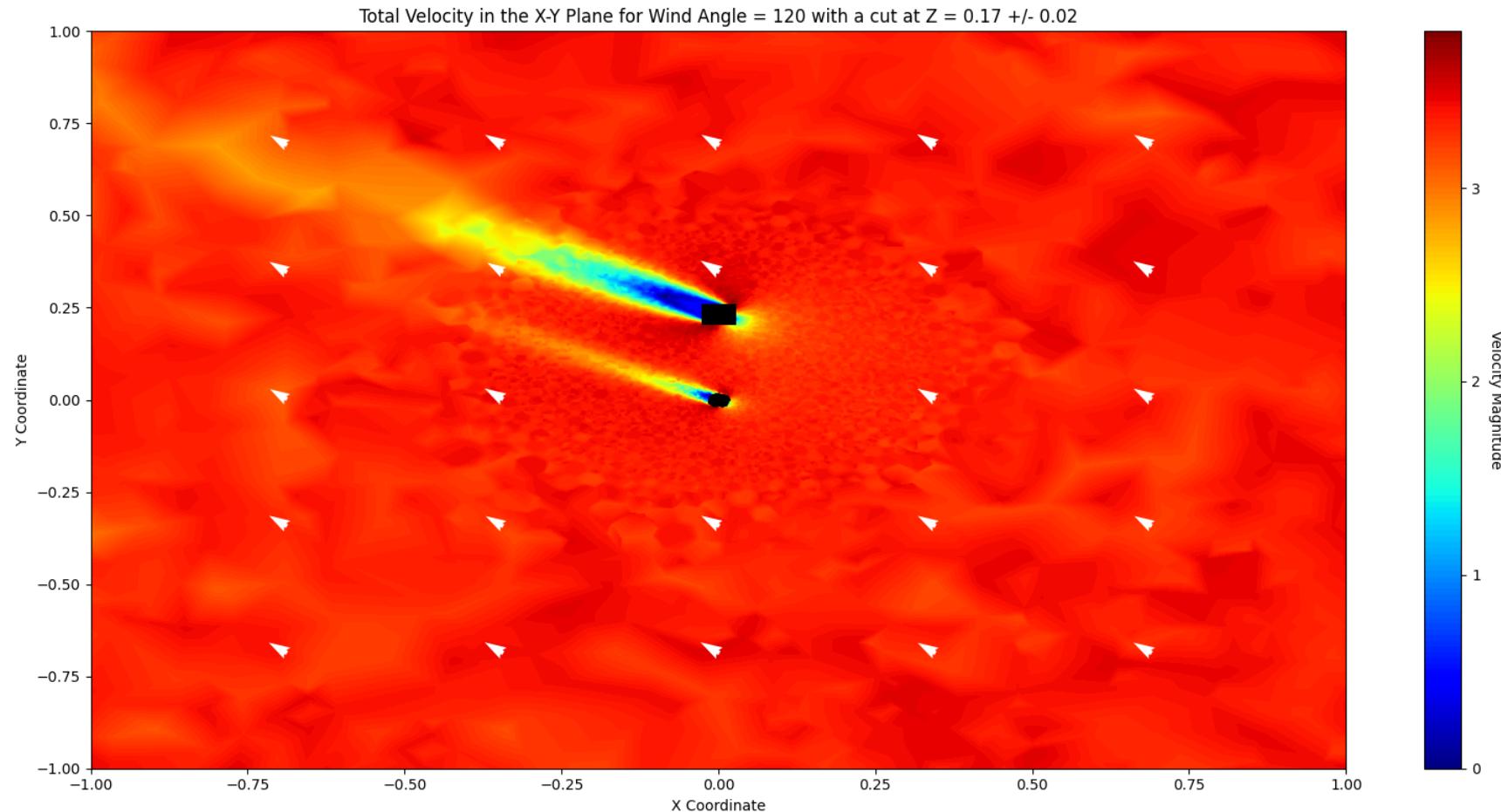
Data Plots – wind angle = 60



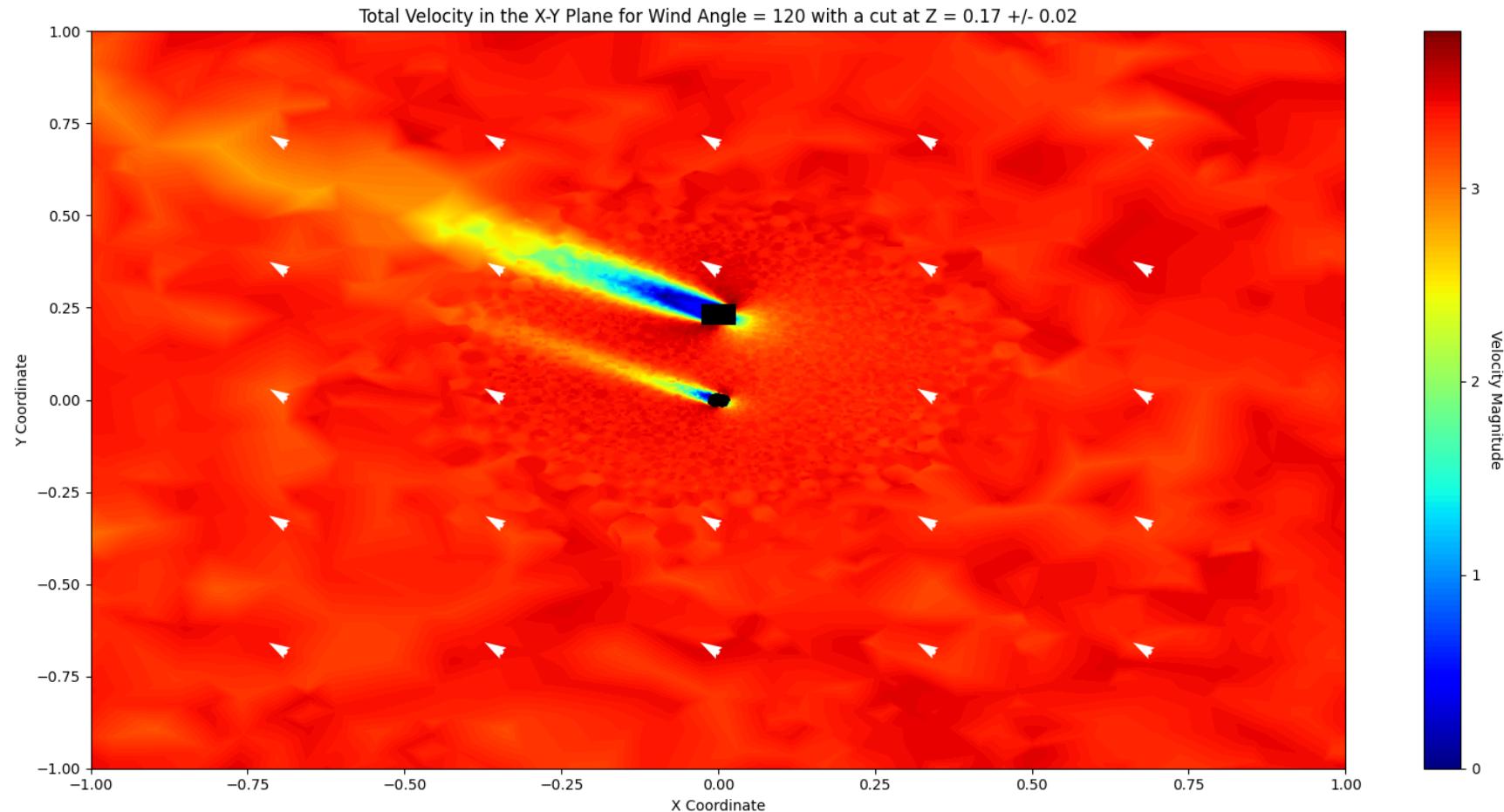
Data Plots – wind angle = 90



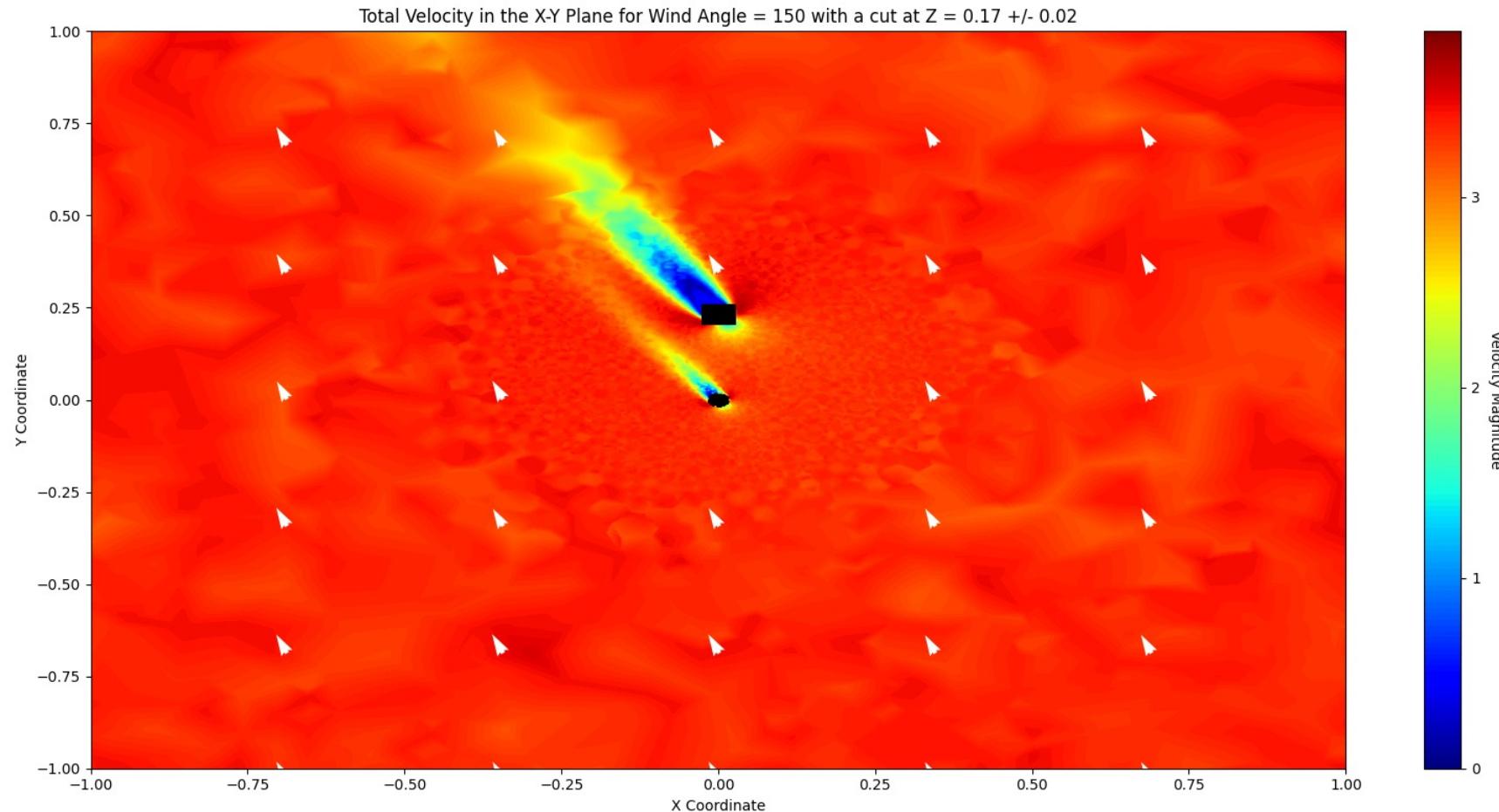
Data Plots – wind angle = 120



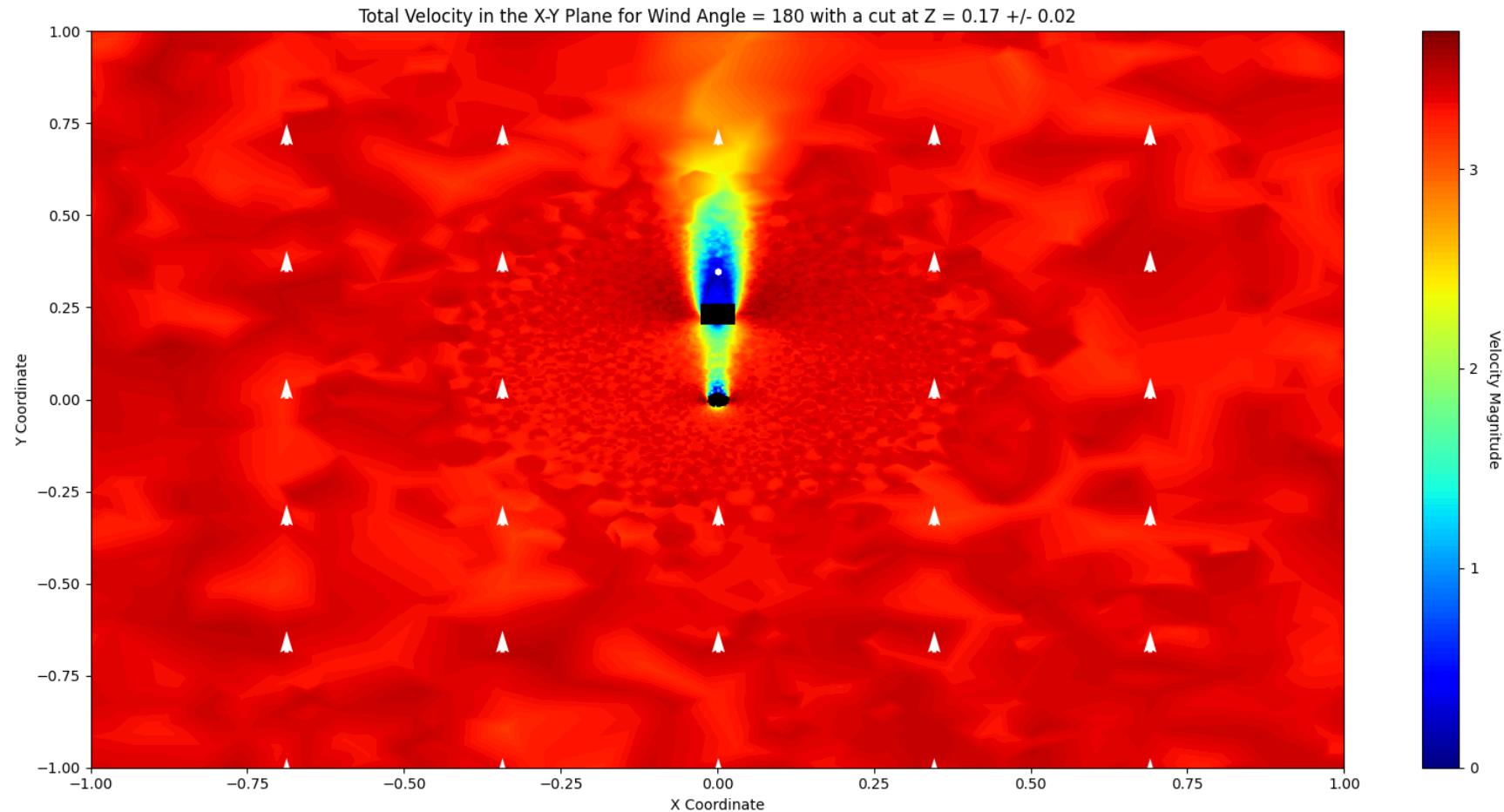
Data Plots – wind angle = 135



Data Plots – wind angle = 150



Data Plots – wind angle = 180



Scripts v3 – Preliminary Results

Some Updates to v3

- 1) Option to overlay plots with quiver arrows in configuration file
- 2) Option to plot for any angle in configuration file
- 3) Number of neurons customizable from configuration file
- 4) Type of activation function customizable
- 5) Type of scaler customizable
- 6) Boundary conditions – no slip, inlet velocity (Dirichlet)
- 7) Custom points for physics loss
- 8) Use of both optimizers (Adam first for an ansatz then LBFGS to fine tune solution)

Some Parameters

Infinite epochs - instead the criteria for stopping is $\text{loss}_{\{n\}} - \text{loss}_{\{n-1\}} < \epsilon$ for 10 consecutive epochs where n is the epoch number and $\epsilon = 1E-5$ (user defined)

128 Neurons for the PINN unless otherwise specified

We have the data for 8 angles, [0, 30, 60, 90, 120, 135, 150, 180] in degrees

We concatenate the data for angles = [0, 30, 60, 90, 120, 150, 180] and then take 99.99% of the dataset with random seed = 42 for training and 0.01% for testing

By using the whole dataset we hope to make the NN learn about wind angle such that the parameters become functions of the wind angle

Then using the trained neural network we predict the data for angle = 135

Progress so far - Data Loss Only
Min-Max Scalar
(Adam Optimizer)

Threshold = 1E-5 (18850 Epochs,
completed), GPU Laptop

Scripts v3 – PREDICTING (135 DEG)

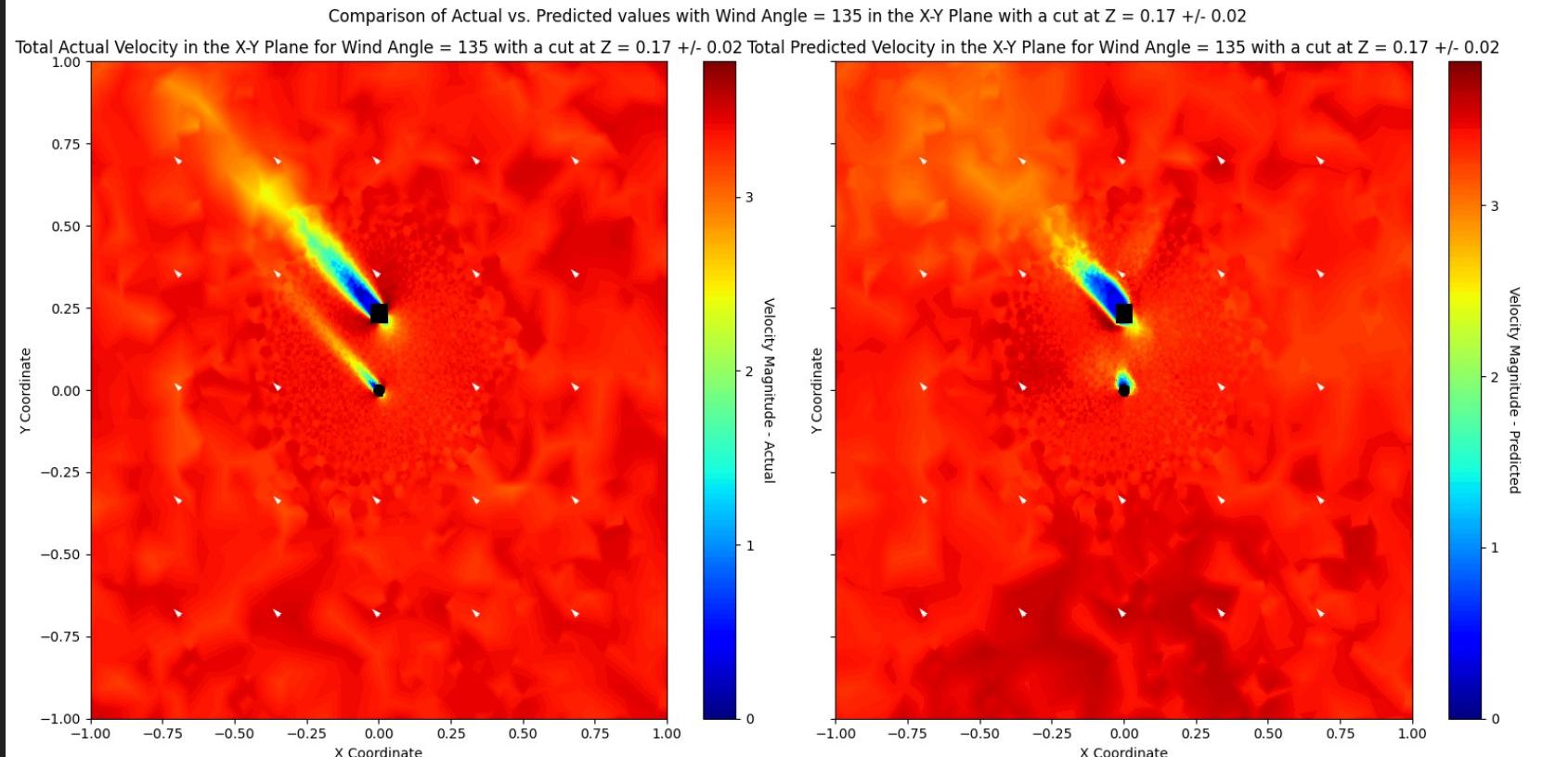
Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar)
Threshold = 1E-5 (18850 Epochs), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	1.03975393	1.01968325	0.43332264	0.38489288
Velocity:0	0.10043868	0.31692062	0.18025719	0.90145605
Velocity:1	0.09228724	0.30378815	0.19015273	0.91031696
Velocity:2	0.03527319	0.18781159	0.07543006	-0.0782273
TurbVisc	0.30357388	0.55097539	0.40223013	0.99778787

Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar)

Threshold = 1E-5 (18850 Epochs), GPU Laptop

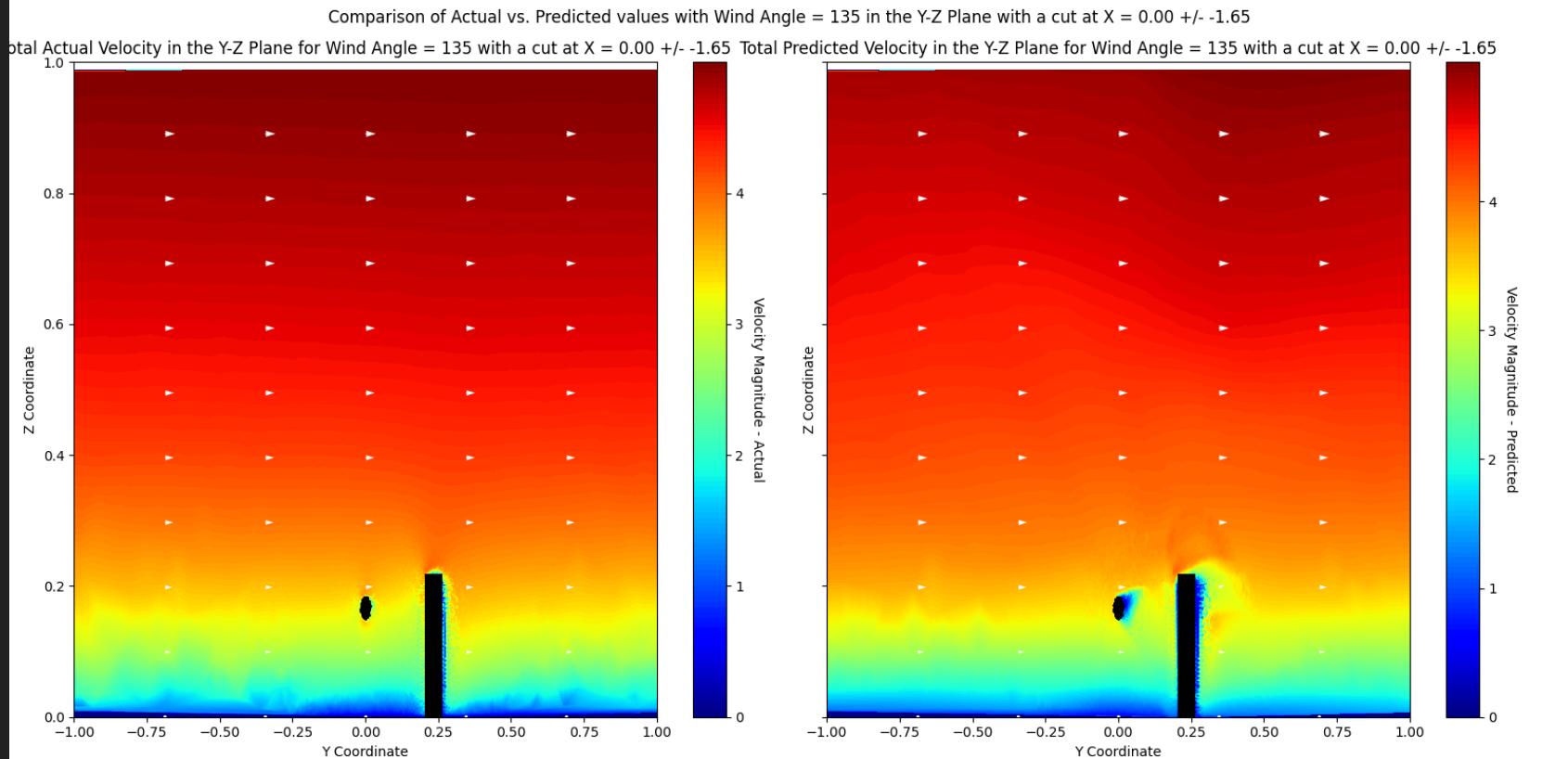
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



Progress so far - Data Loss Only (Adam Optimizer – Min-Max Scalar)

Threshold = 1E-5 (18850 Epochs), GPU Laptop

Predicting Results - Y-Z Total Velocity Plot (Angle = 135)



Progress so far - Data Loss Only
Standard Normal Scalar
(Adam Optimizer)

Threshold = 1E-5 (19175 Epochs, not completed), GPU Laptop

Scripts v3 – PREDICTING (135 DEG)

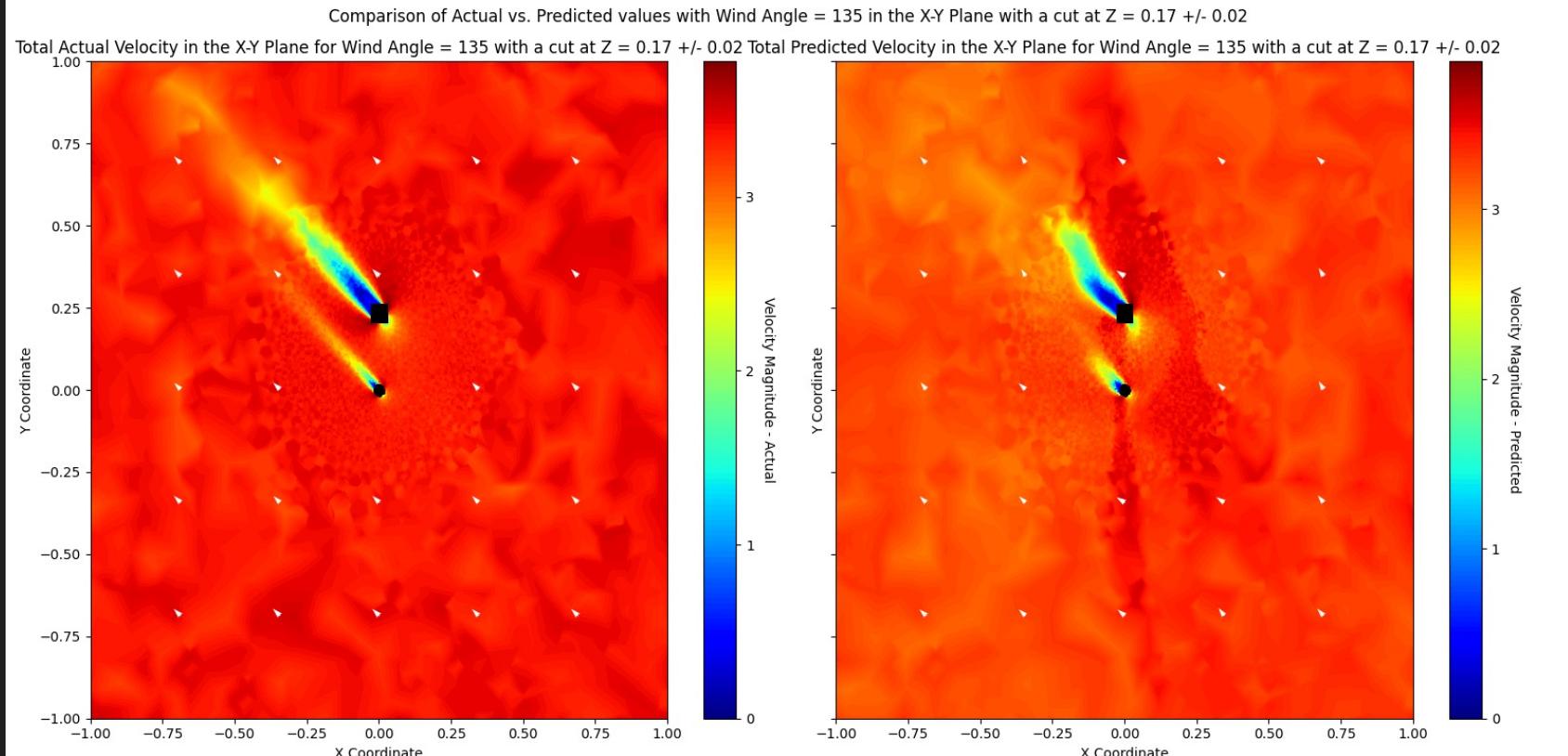
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (19175 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	0.78156245	0.88406021	0.83353646	0.53763615
Velocity:0	0.26816494	0.51784645	0.43721107	0.73689386
Velocity:1	0.16554396	0.40687094	0.34393418	0.83912743
Velocity:2	0.00284464	0.05333518	0.02176775	0.9130453
TurbVisc	0.21766559	0.46654645	0.35251983	0.99841388

Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)

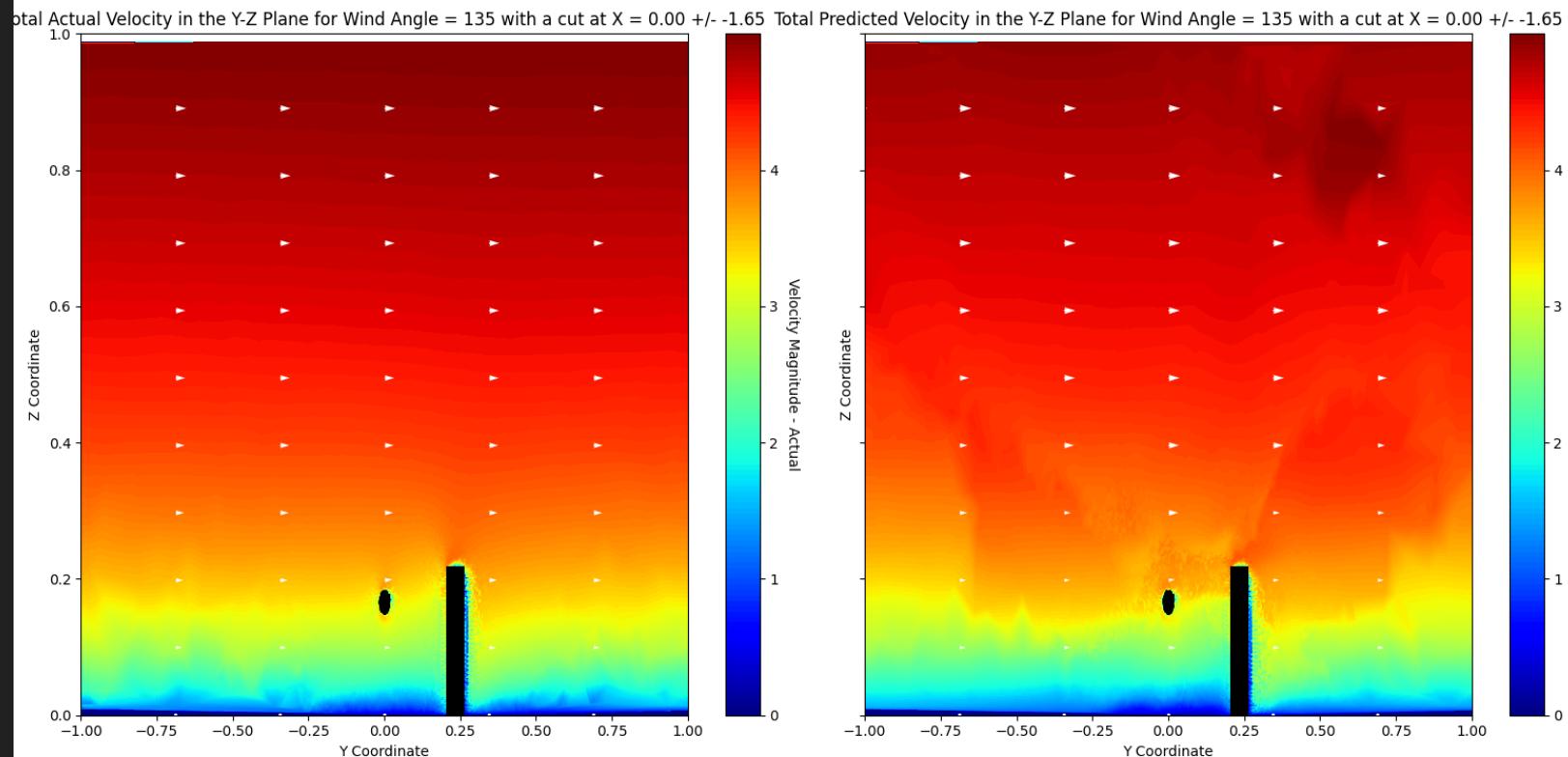
Threshold = 1E-5 (19175 Epochs, so far...), GPU Laptop

Predicting Results - X-Y Total Velocity Plot (Angle = 135)



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (19175 Epochs, so far...), GPU Laptop
Predicting Results - Y-Z Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the Y-Z Plane with a cut at X = 0.00 +/- 1.65



Progress so far - Data Loss Only
64 Neurons
(Adam Optimizer)

Threshold = 1E-5 (3243 Epochs,
completed), GPU Laptop

Scripts v3 – PREDICTING (135 DEG)

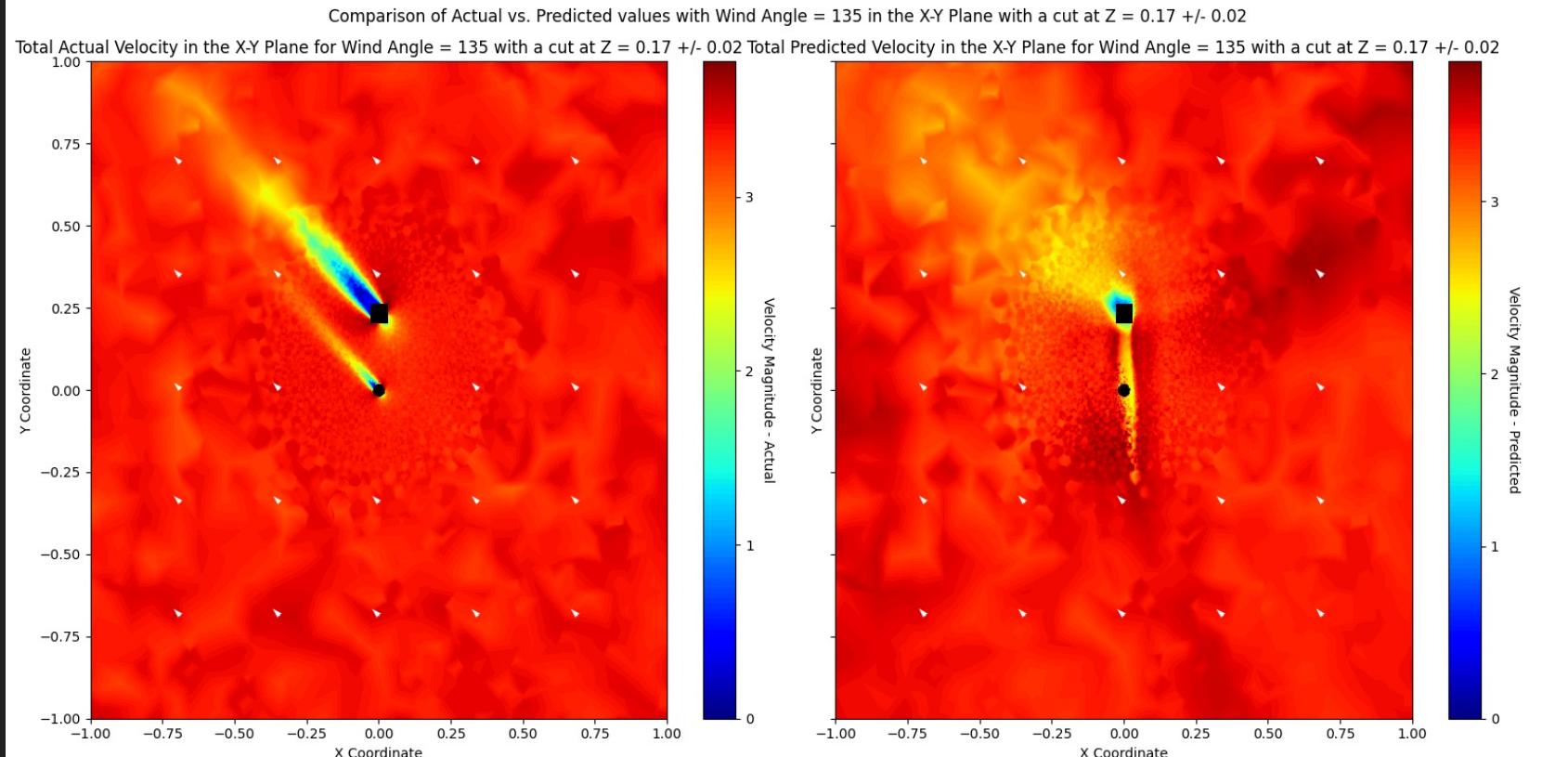
Progress so far - Data Loss Only (Adam Optimizer – 64 Neurons)
Threshold = 1E-5 (3243 Epochs), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	0.85800617	0.92628623	0.45946521	0.49241287
Velocity:0	0.11403625	0.33769254	0.20760991	0.88811499
Velocity:1	0.14217006	0.37705446	0.22903378	0.86184175
Velocity:2	0.01153235	0.1073888	0.04620757	0.6474802
TurbVisc	0.67781433	0.8232948	0.63516461	0.99506079

Progress so far - Data Loss Only (Adam Optimizer – 64 Neurons)

Threshold = 1E-5 (3243 Epochs), GPU Laptop

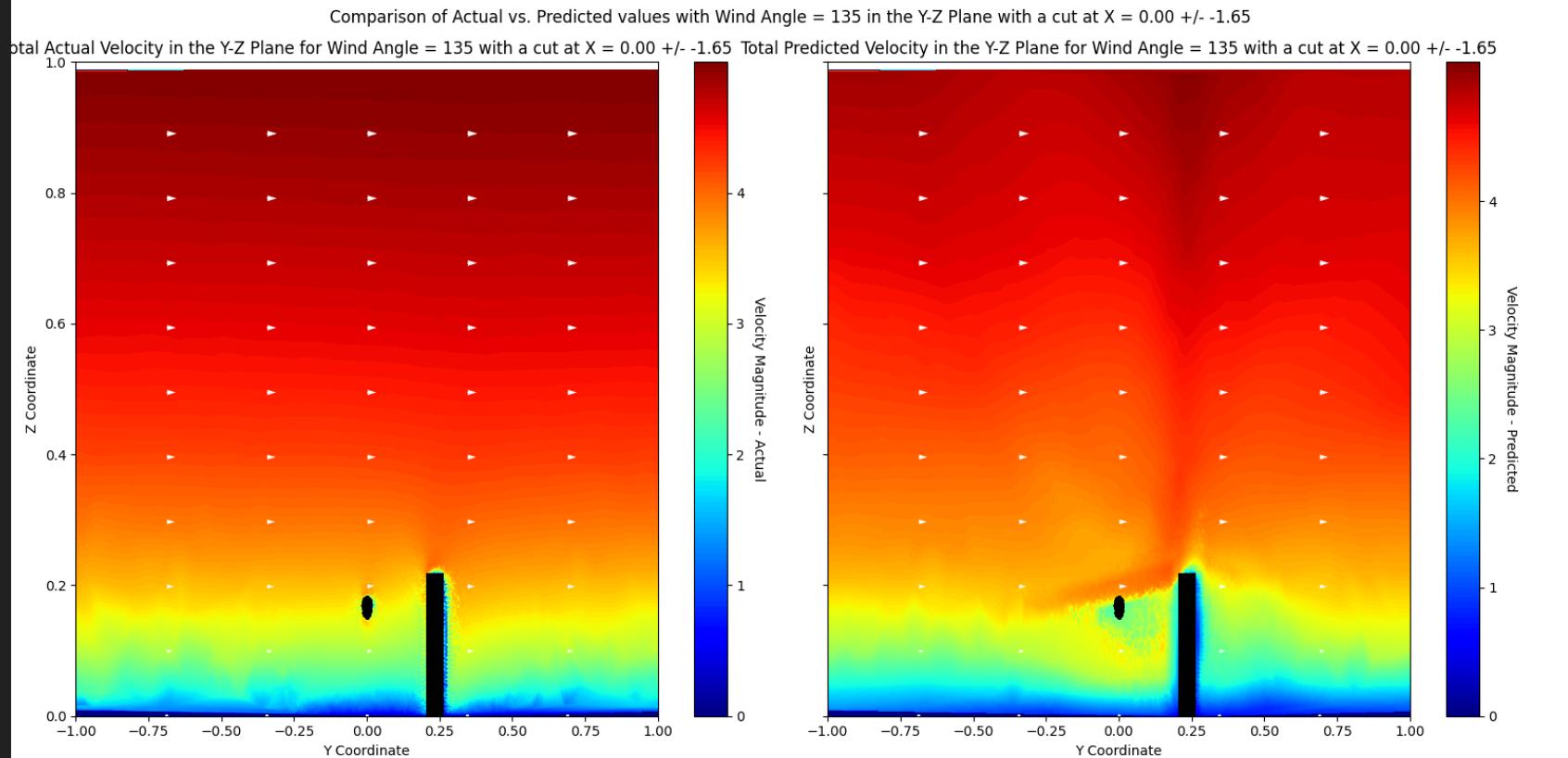
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



Progress so far - Data Loss Only (Adam Optimizer – 64 Neurons)

Threshold = 1E-5 (3243 Epochs), GPU Laptop

Predicting Results - Y-Z Total Velocity Plot (Angle = 135)



Progress so far - Data Loss + Cont Loss
(with Boundary Conditions imposed)
(Adam Optimizer)

Threshold = 1E-5 (1140 Epochs, not completed), GPU Workstation

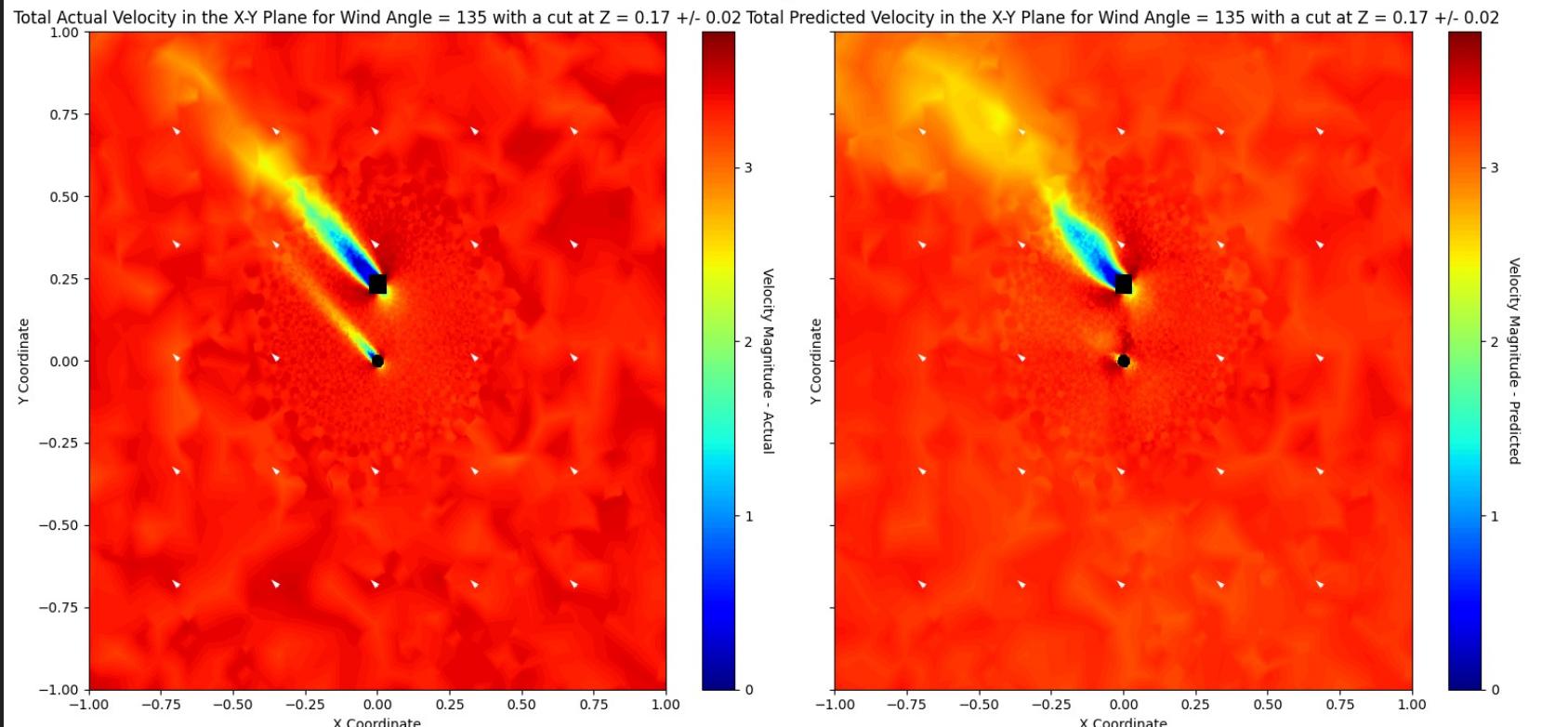
Scripts v3 – PREDICTING (135 DEG)

Progress so far - Data + Cont + Boundary Loss (Adam Optimizer)
Threshold = 1E-5 (1140 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Pressure	0.36050427	0.60042008	0.47316831	0.78672959
Velocity:0	0.09035001	0.30058279	0.16776892	0.9113544
Velocity:1	0.08495821	0.29147591	0.22463445	0.91743918
Velocity:2	0.01257354	0.1121318	0.0333293	0.61565332
TurbVisc	0.14515815	0.38099625	0.27152452	0.99894224

Progress so far - Data + Cont + Boundary Loss (Adam Optimizer)
Threshold = 1E-5 (1140 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

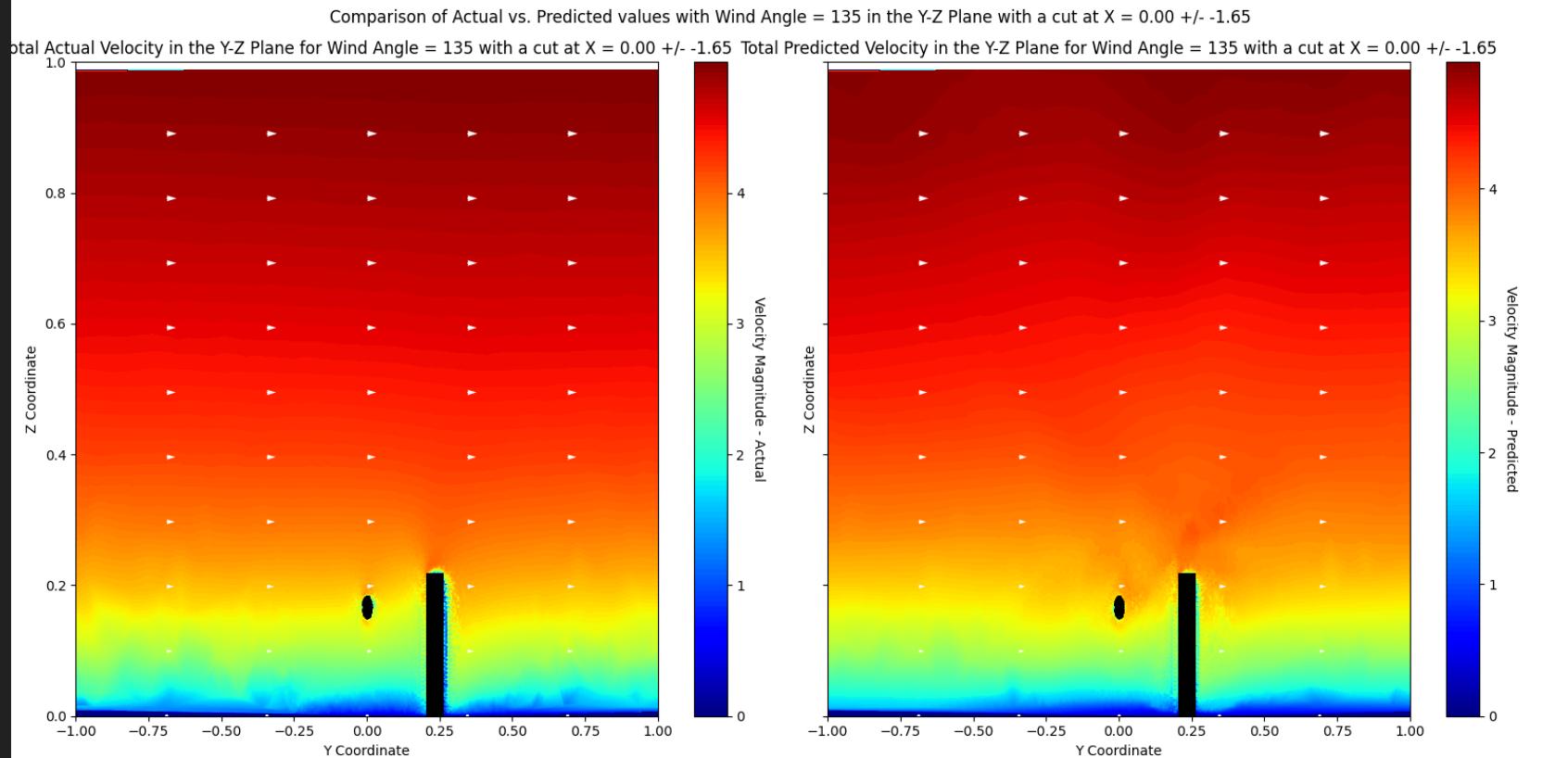
Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Progress so far - Data + Cont + Boundary Loss (Adam Optimizer)

Threshold = 1E-5 (1140 Epochs, so far...), GPU Workstation

Predicting Results - Y-Z Total Velocity Plot (Angle = 135)



Statistical Comparisons

Statistical Comparisons - MSE

Type	Data – Std Normal (NC)	Data – Min-Max (C)	Data – 64 Neurons (C)	Data + Cont + Boundary (NC)
Pressure	0.78156245	1.03975393	0.85800617	0.36050427
Velocity:0	0.26816494	0.10043868	0.11403625	0.09035001
Velocity:1	0.16554396	0.09228724	0.14217006	0.08495821
Velocity:2	0.00284464	0.03527319	0.01153235	0.01257354
TurbVisc	0.21766559	0.30357388	0.67781433	0.14515815

Statistical Comparisons – R2

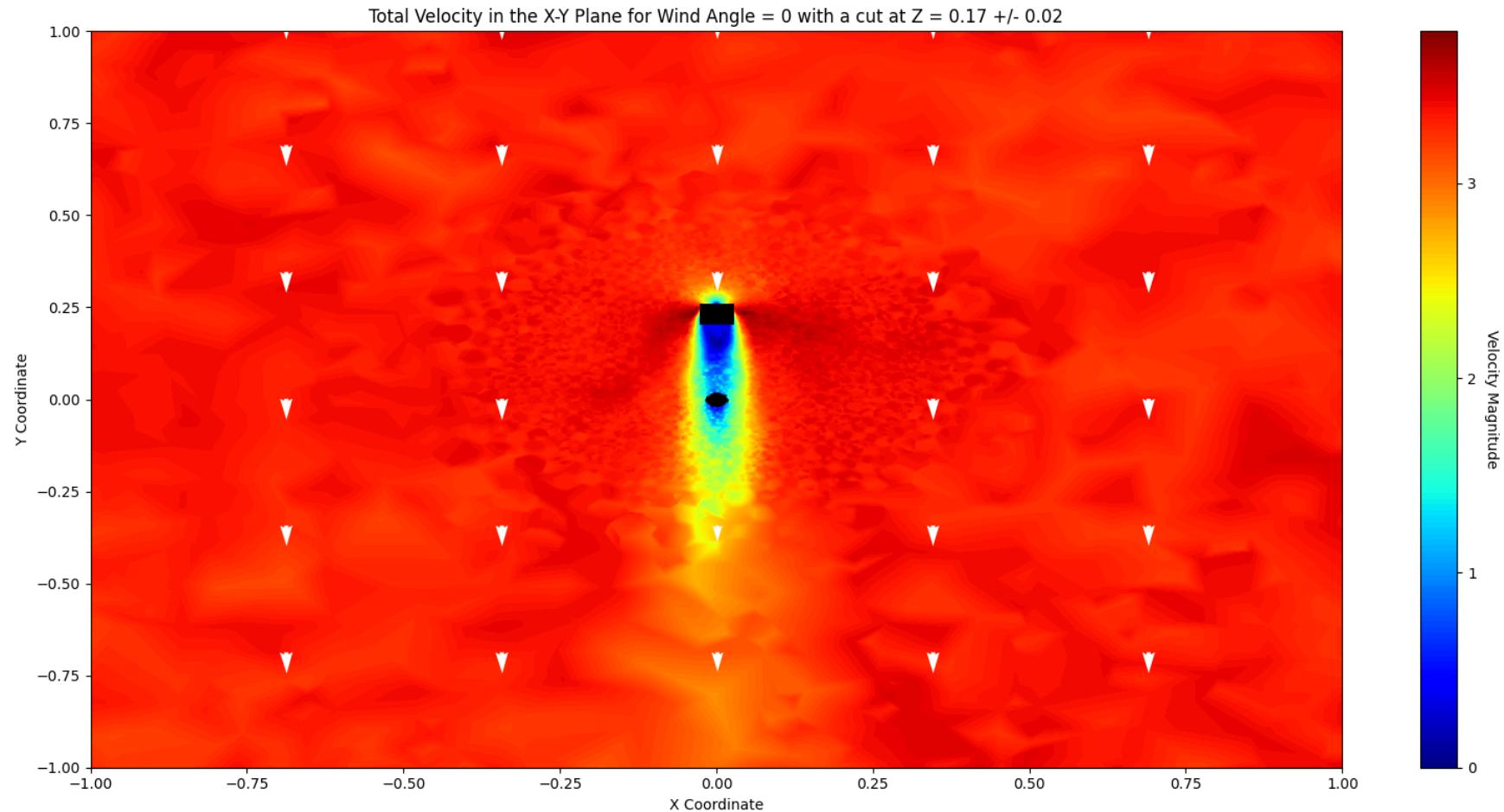
Type	Data – Std Normal (NC)	Data – Min-Max (C)	Data – 64 Neurons (C)	Data + Cont + Boundary (NC)
Pressure	0.53763615	0.38489288	0.49241287	0.78672959
Velocity:0	0.73689386	0.90145605	0.88811499	0.9113544
Velocity:1	0.83912743	0.91031696	0.86184175	0.91743918
Velocity:2	0.9130453	-0.0782273	0.6474802	0.61565332
TurbVisc	0.99841388	0.99778787	0.99506079	0.99894224

Progress so far - Data Loss Only
Standard Normal Scalar
(Adam Optimizer)

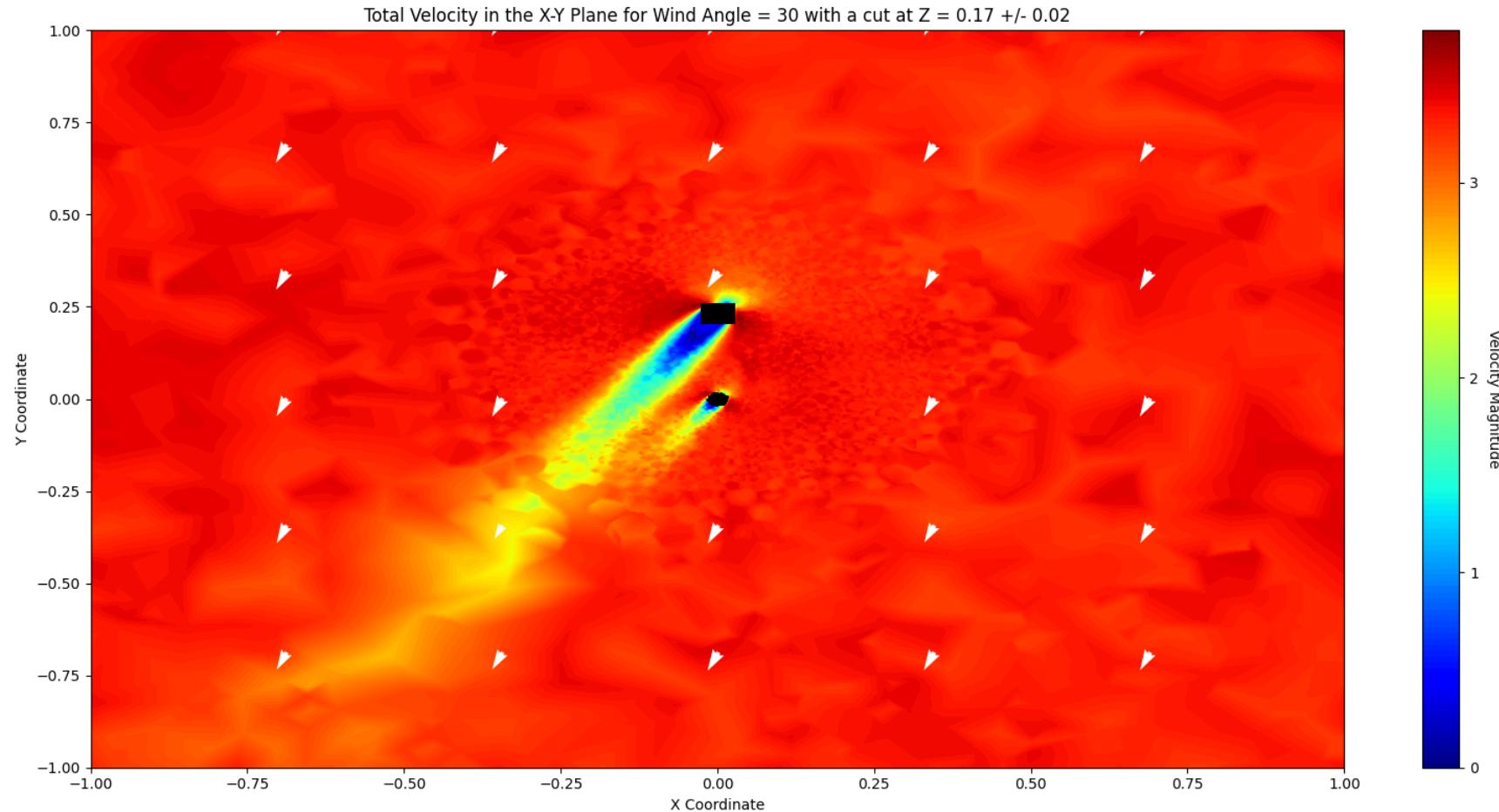
Threshold = 1E-5 (19175 Epochs, not completed), GPU Laptop

Scripts v3 – Plotting Any Angle

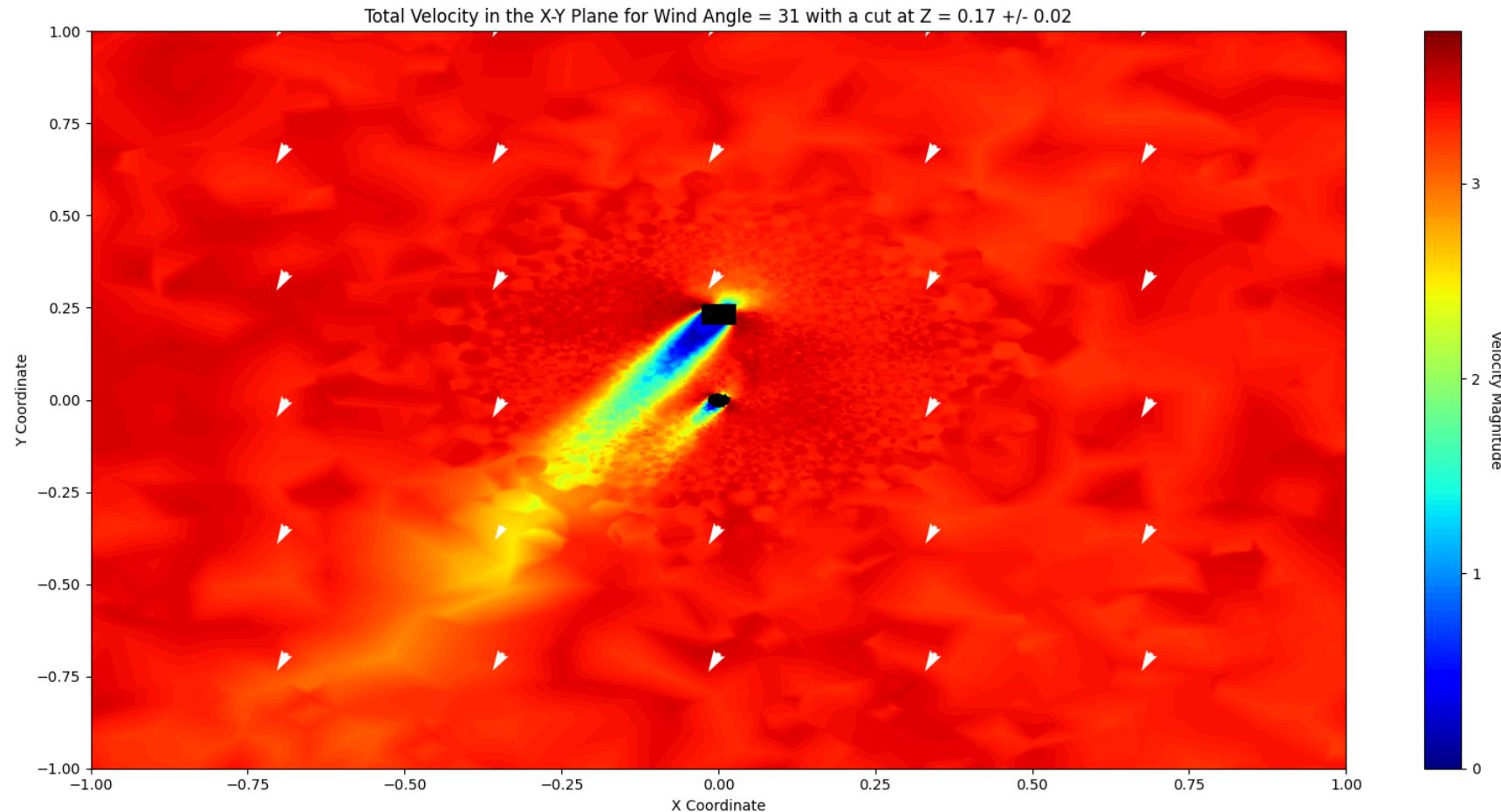
Data Plots – wind angle = 0



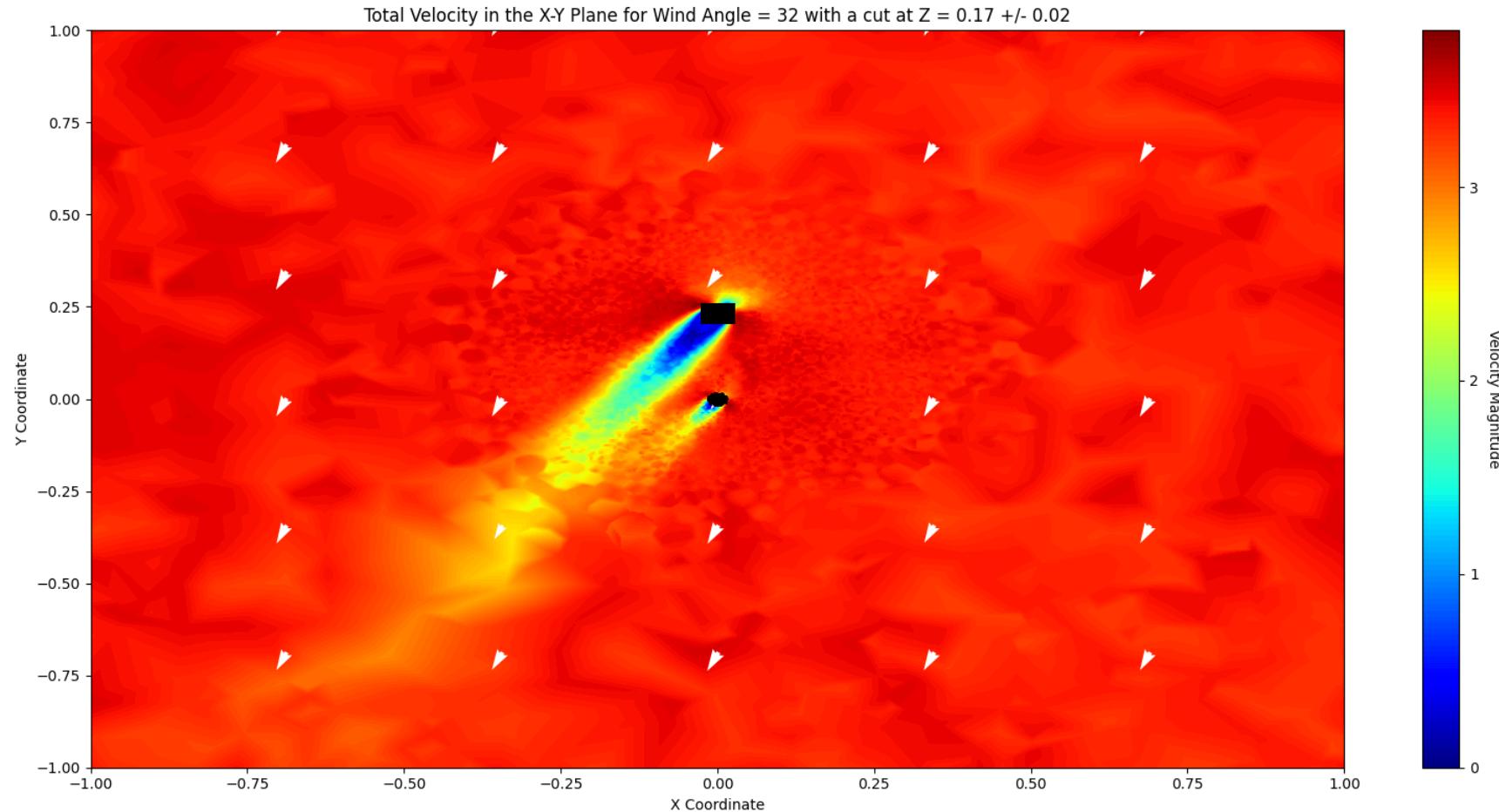
Data Plots – wind angle = 30



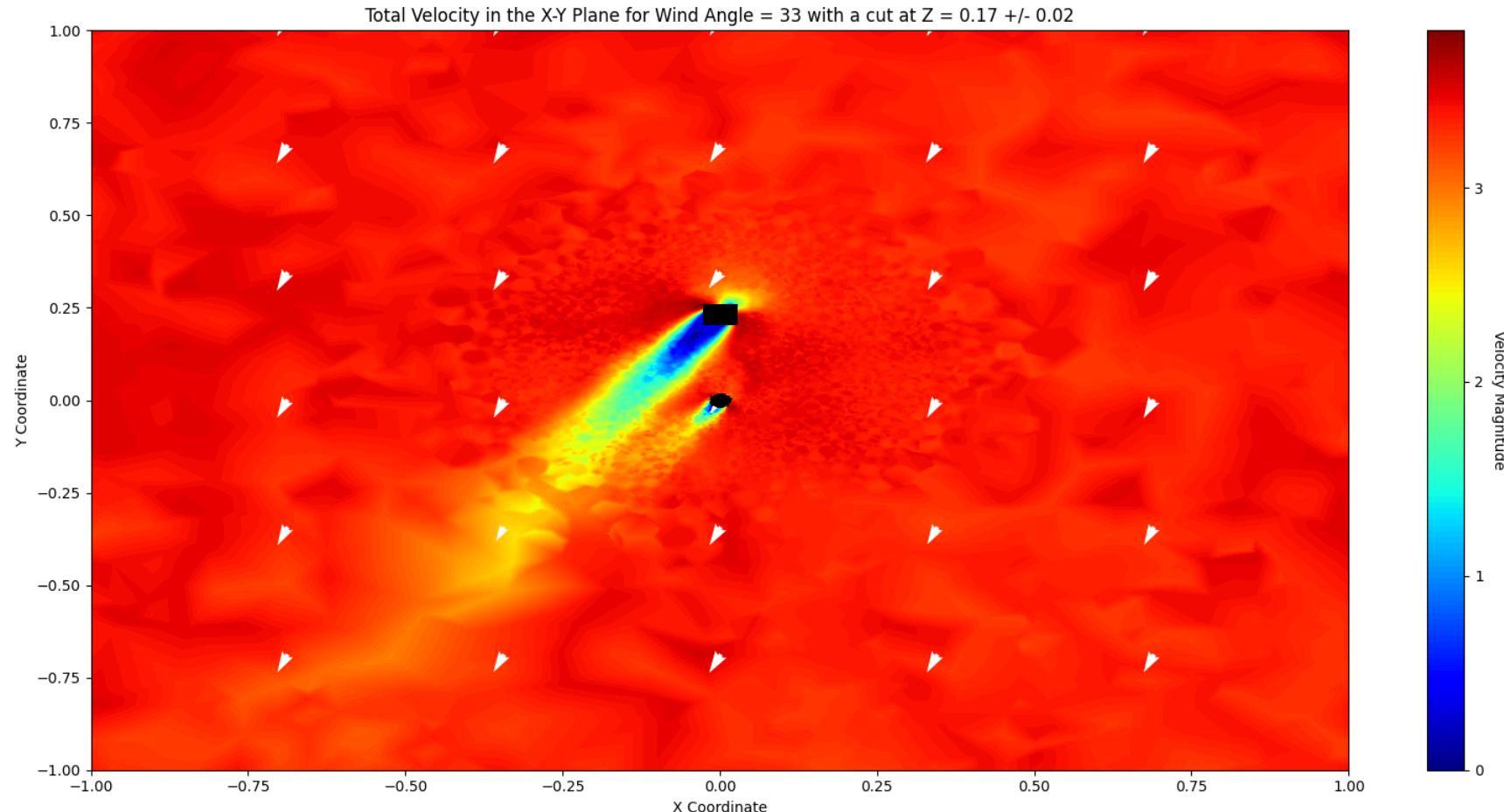
Data Plots – wind angle = 31



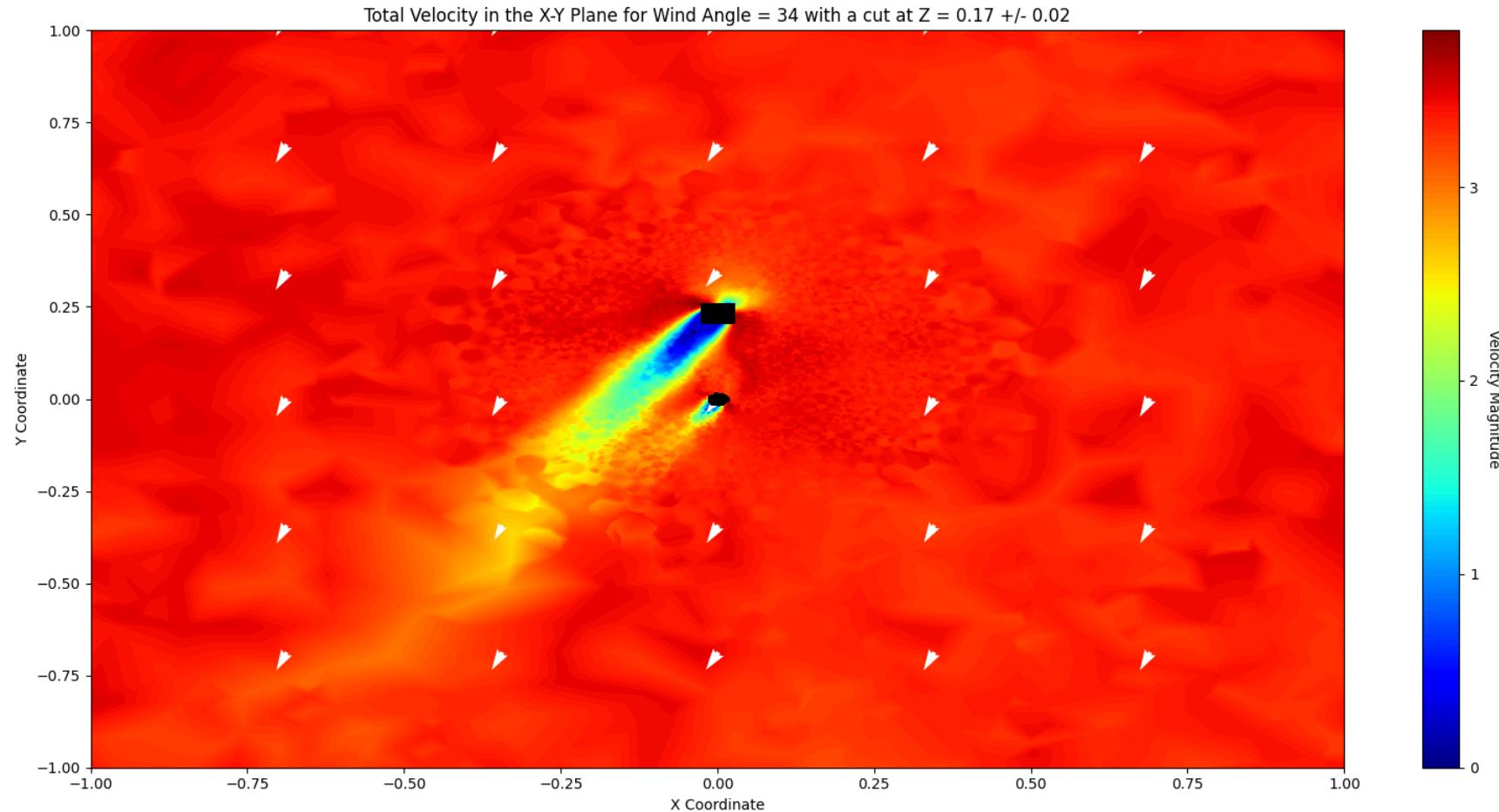
Data Plots – wind angle = 32



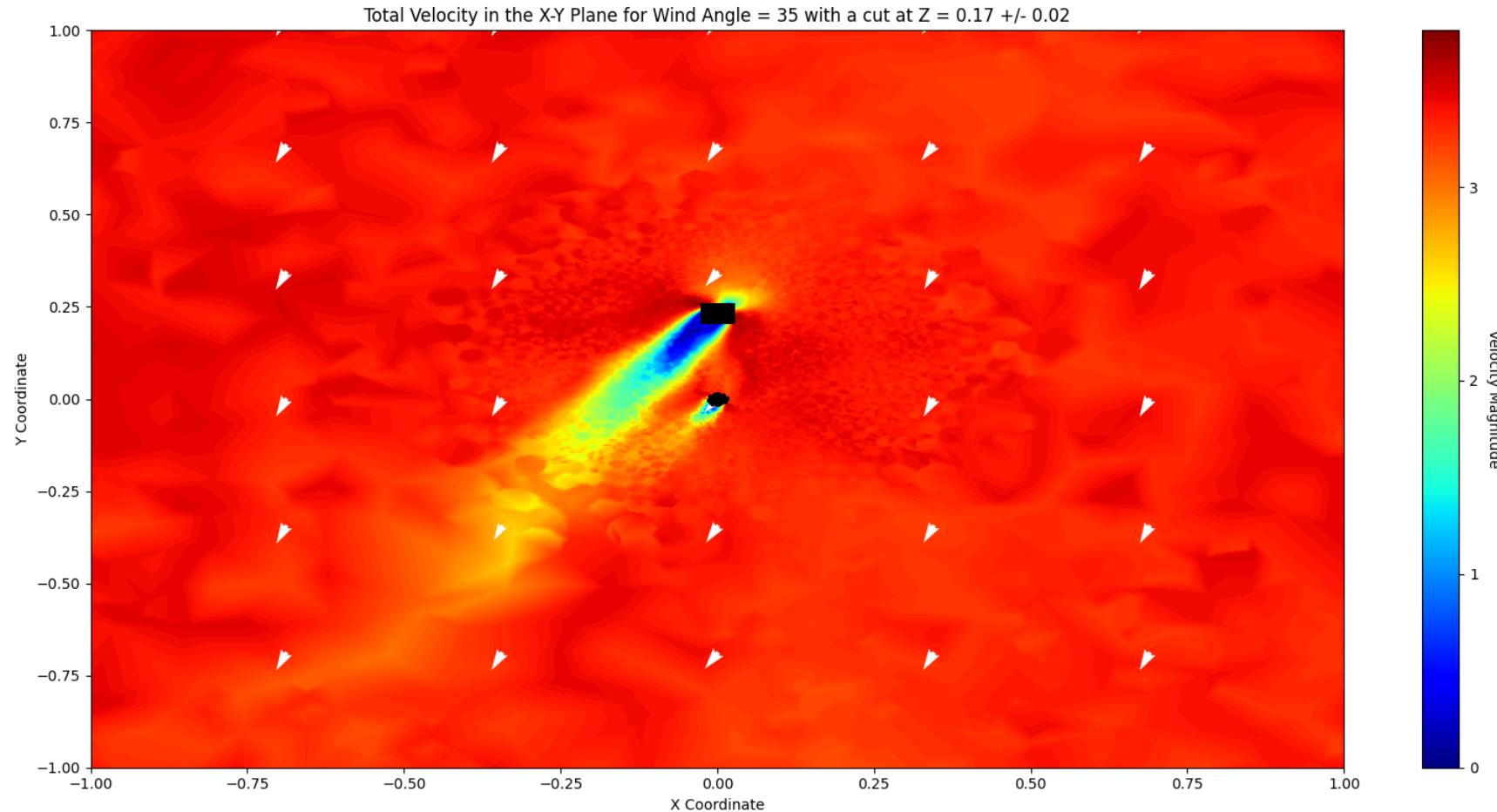
Data Plots – wind angle = 33



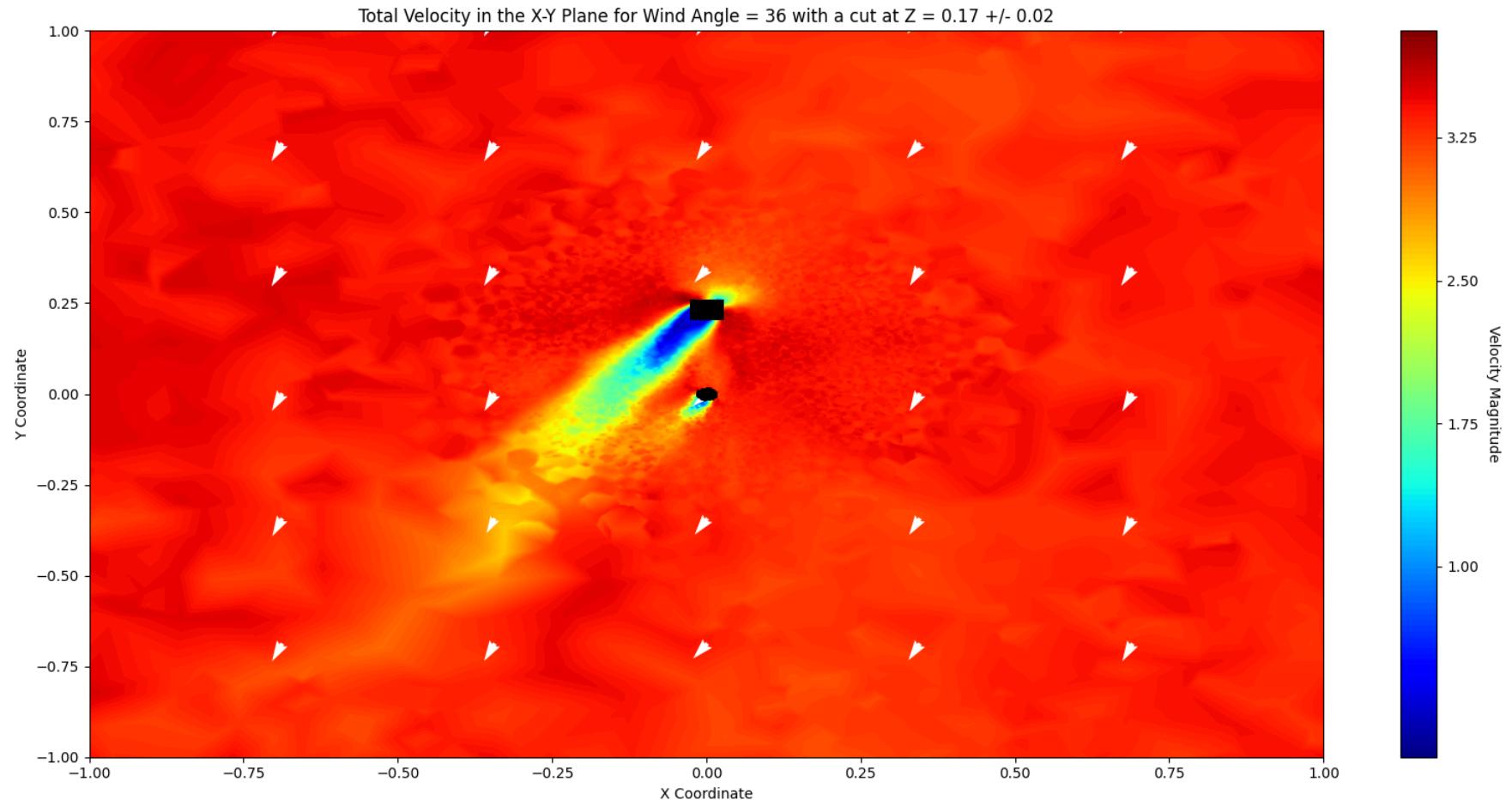
Data Plots – wind angle = 34



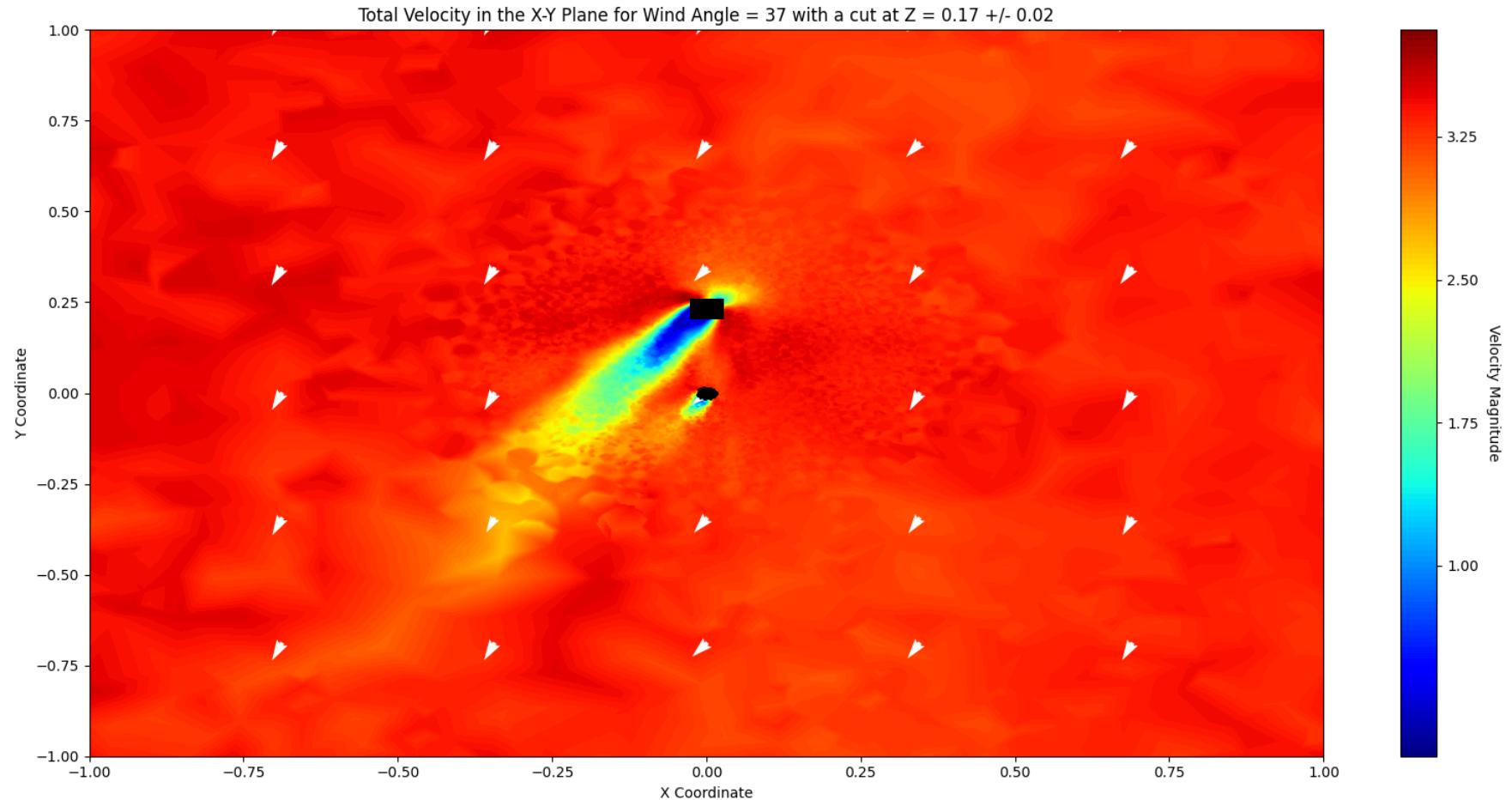
Data Plots – wind angle = 35



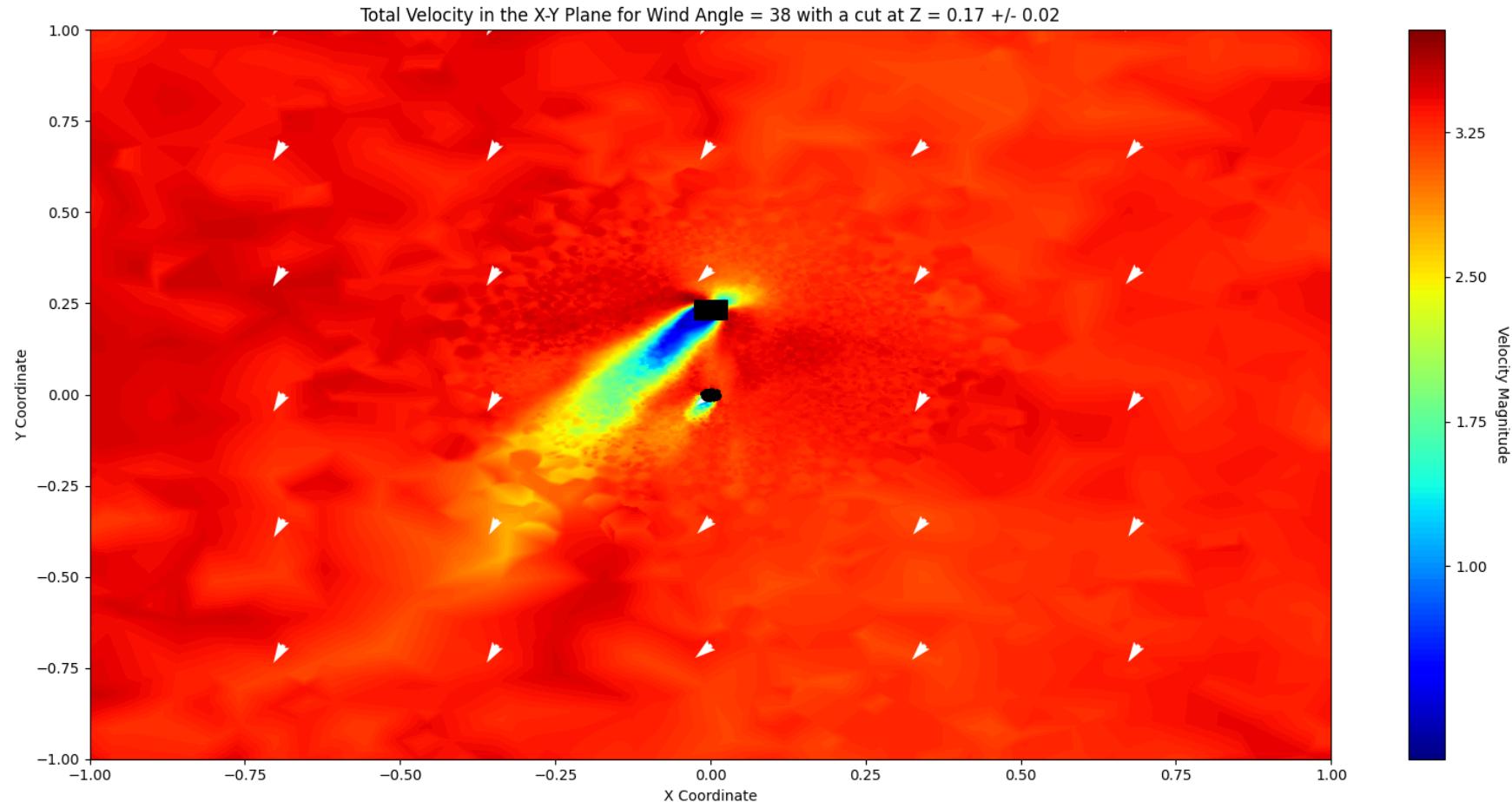
Data Plots – wind angle = 36



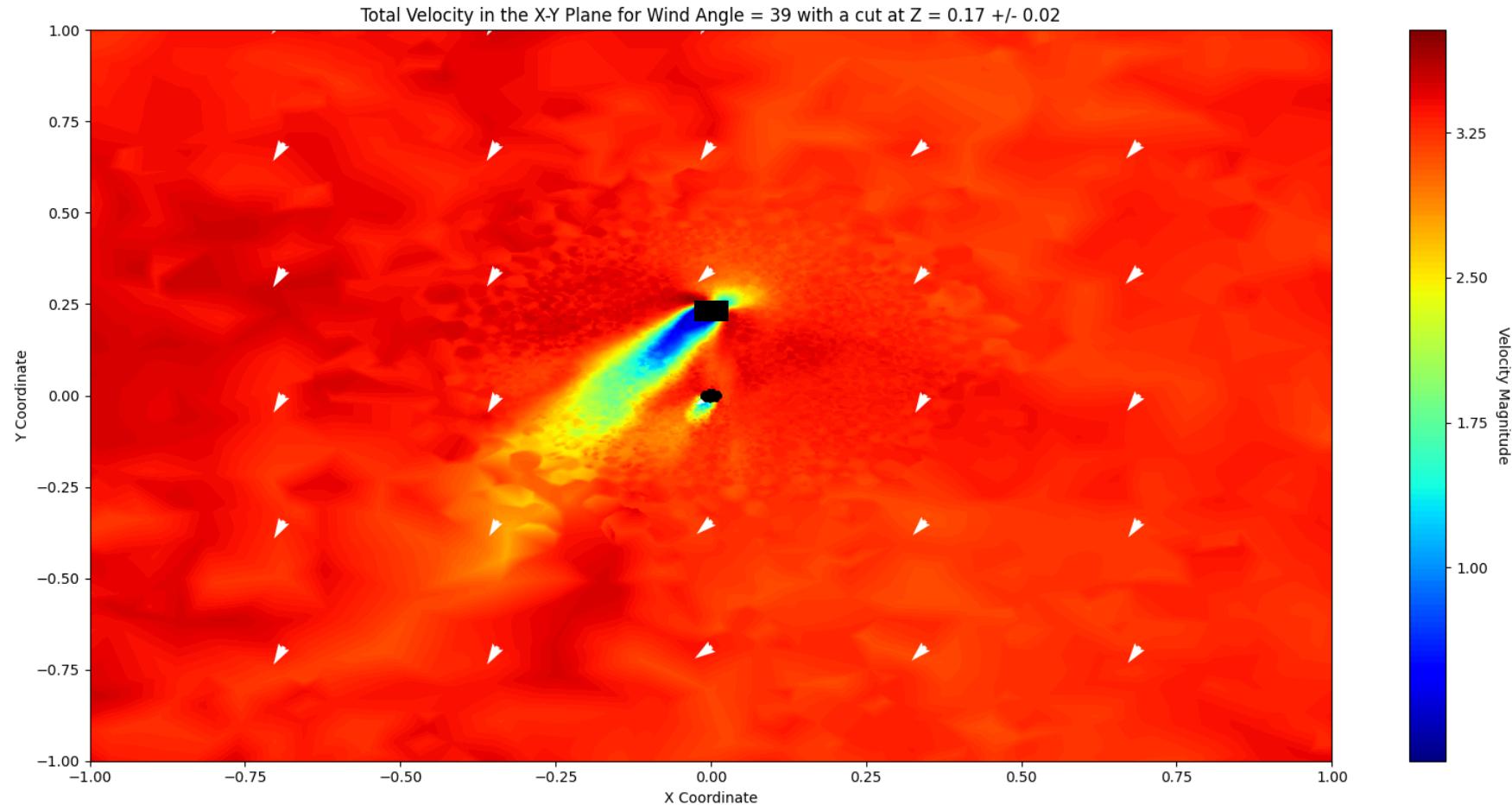
Data Plots – wind angle = 37



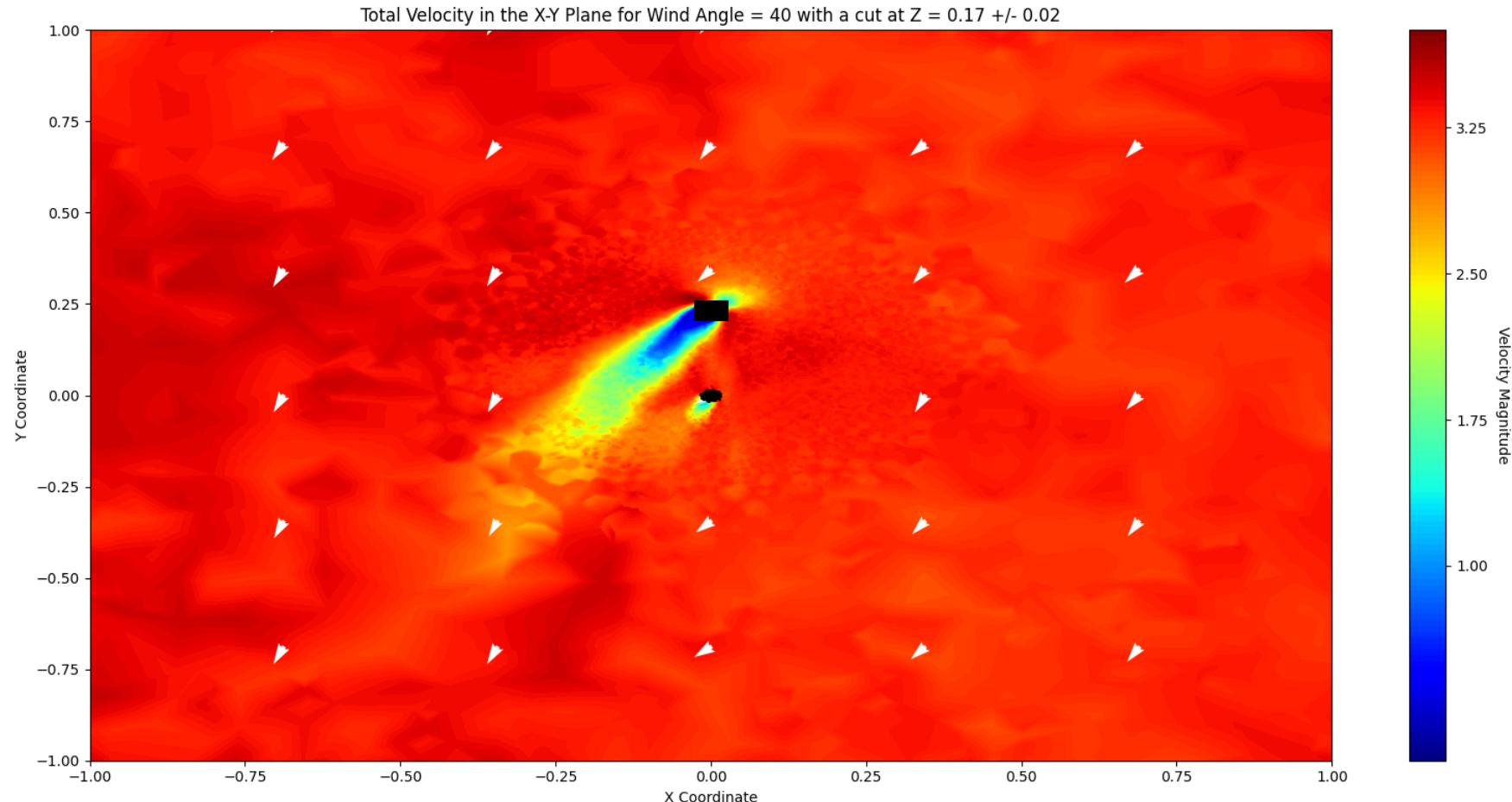
Data Plots – wind angle = 38



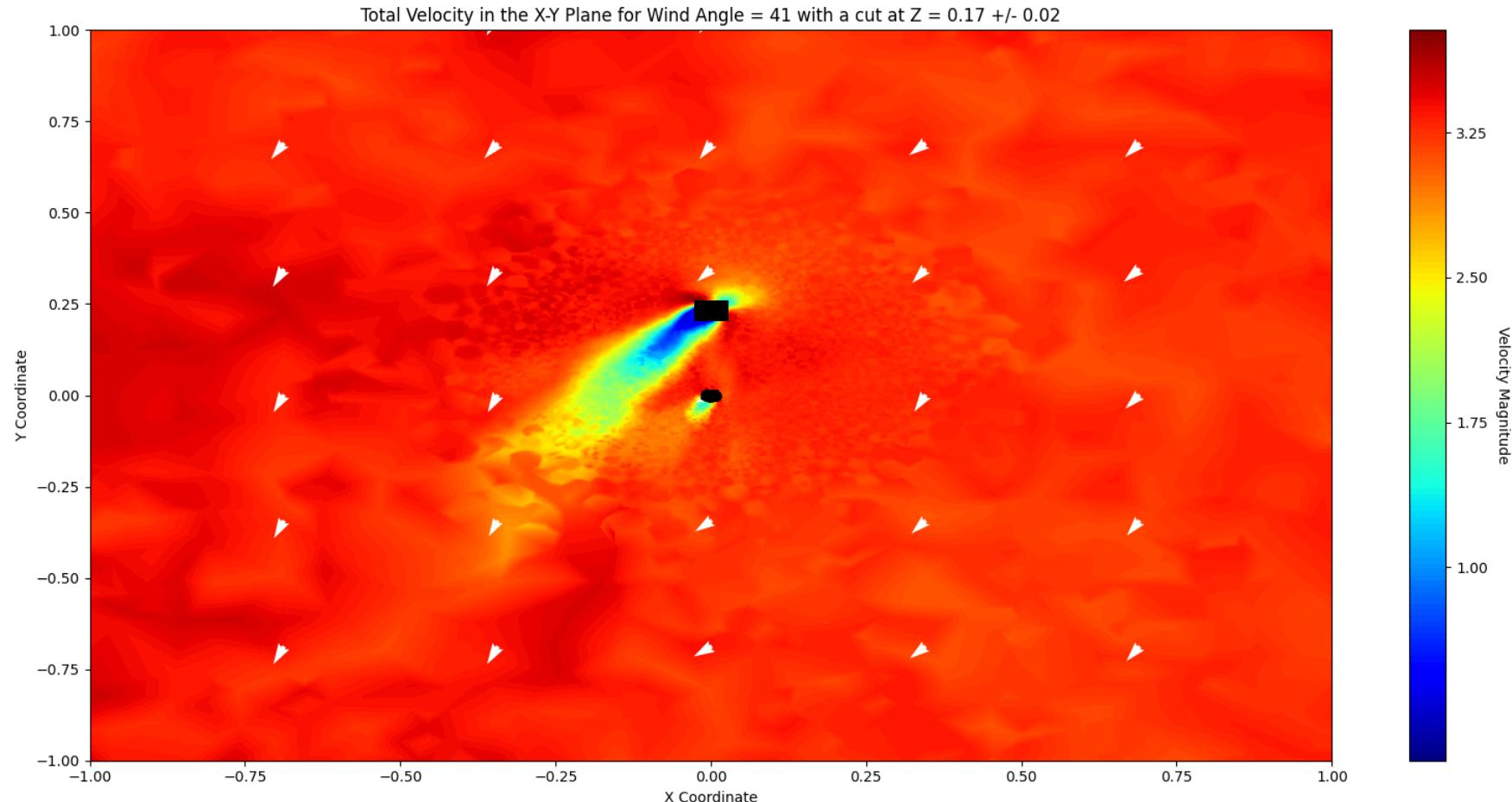
Data Plots – wind angle = 39



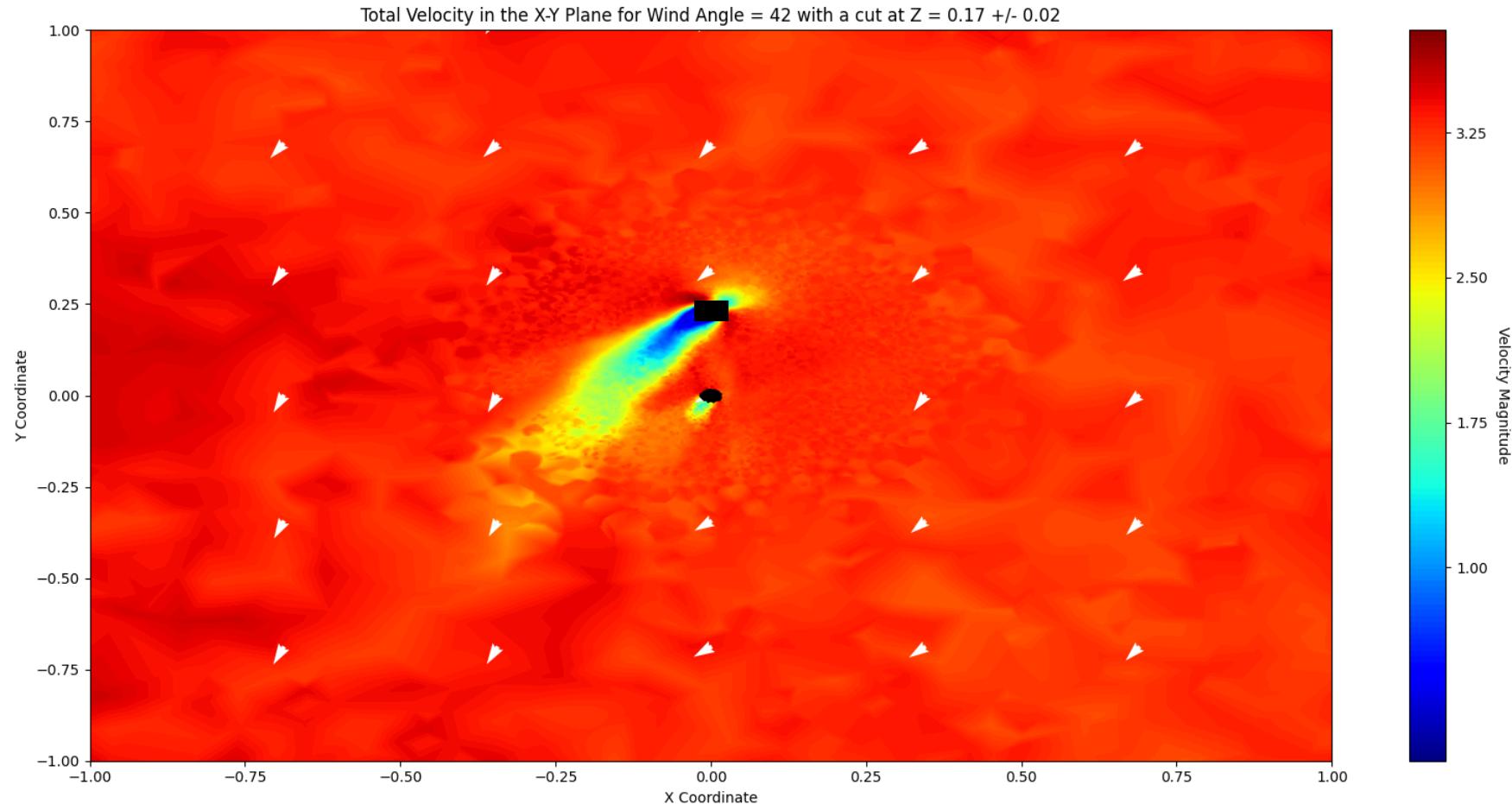
Data Plots – wind angle = 40



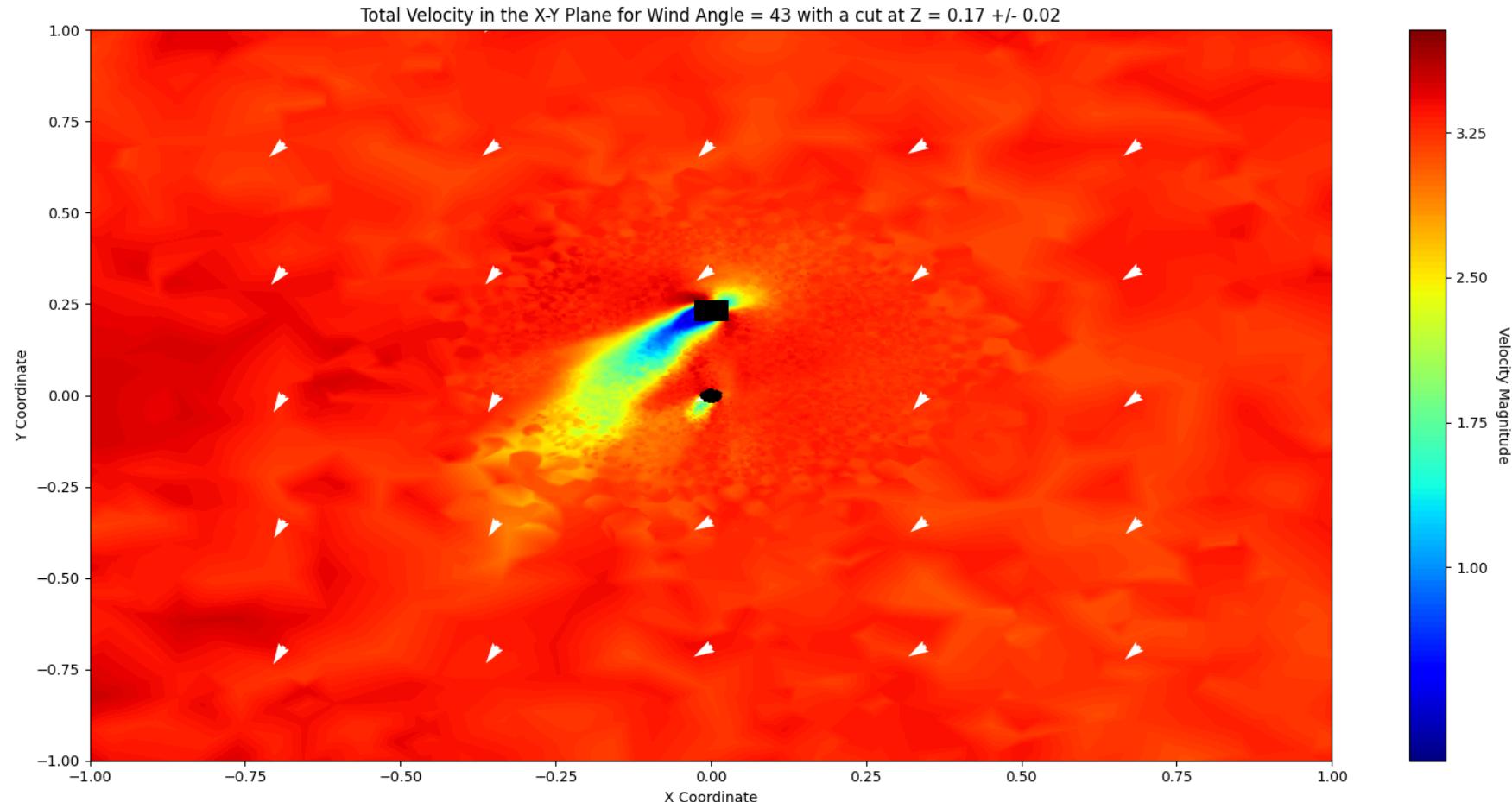
Data Plots – wind angle = 41



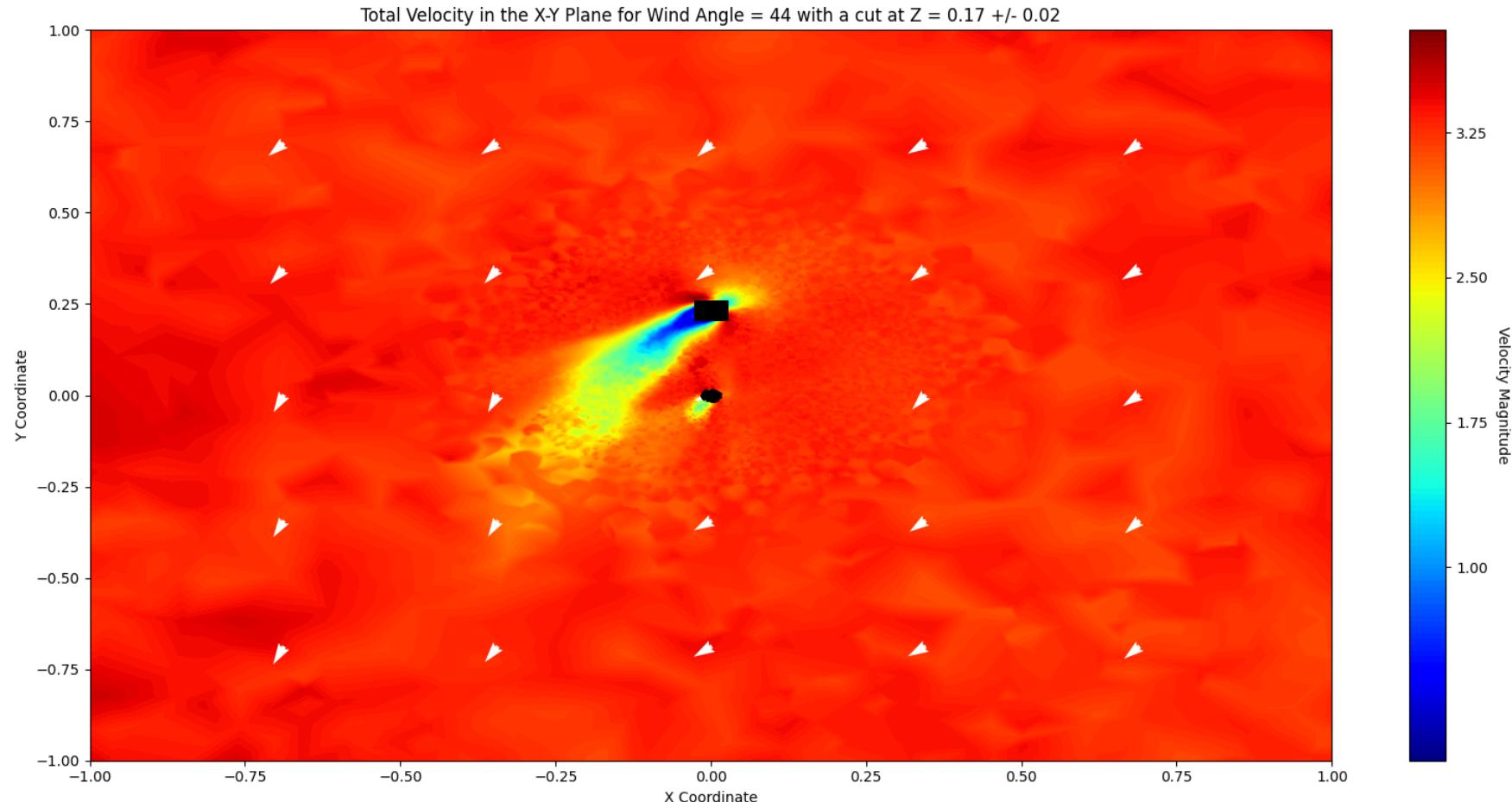
Data Plots – wind angle = 42



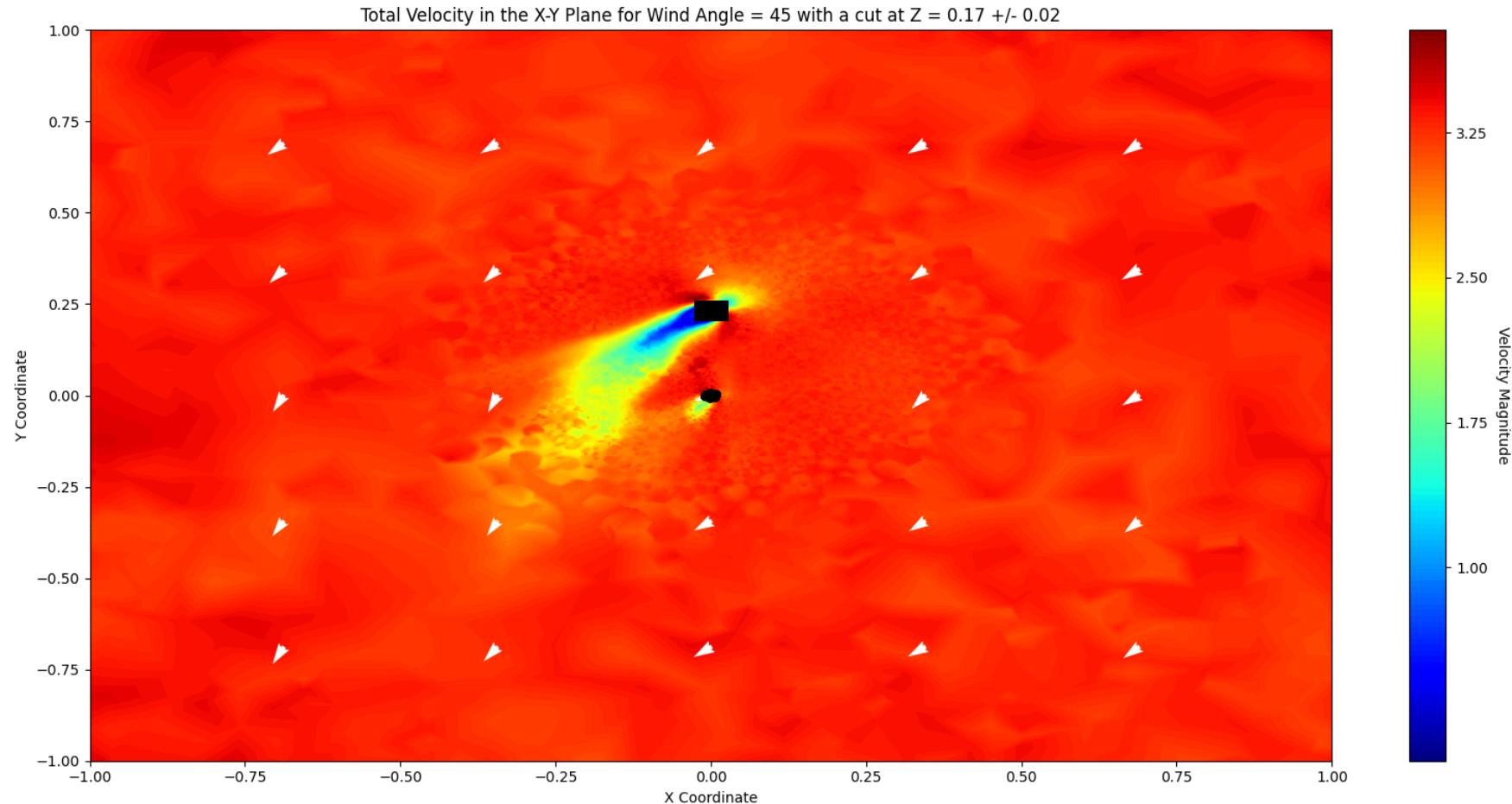
Data Plots – wind angle = 43



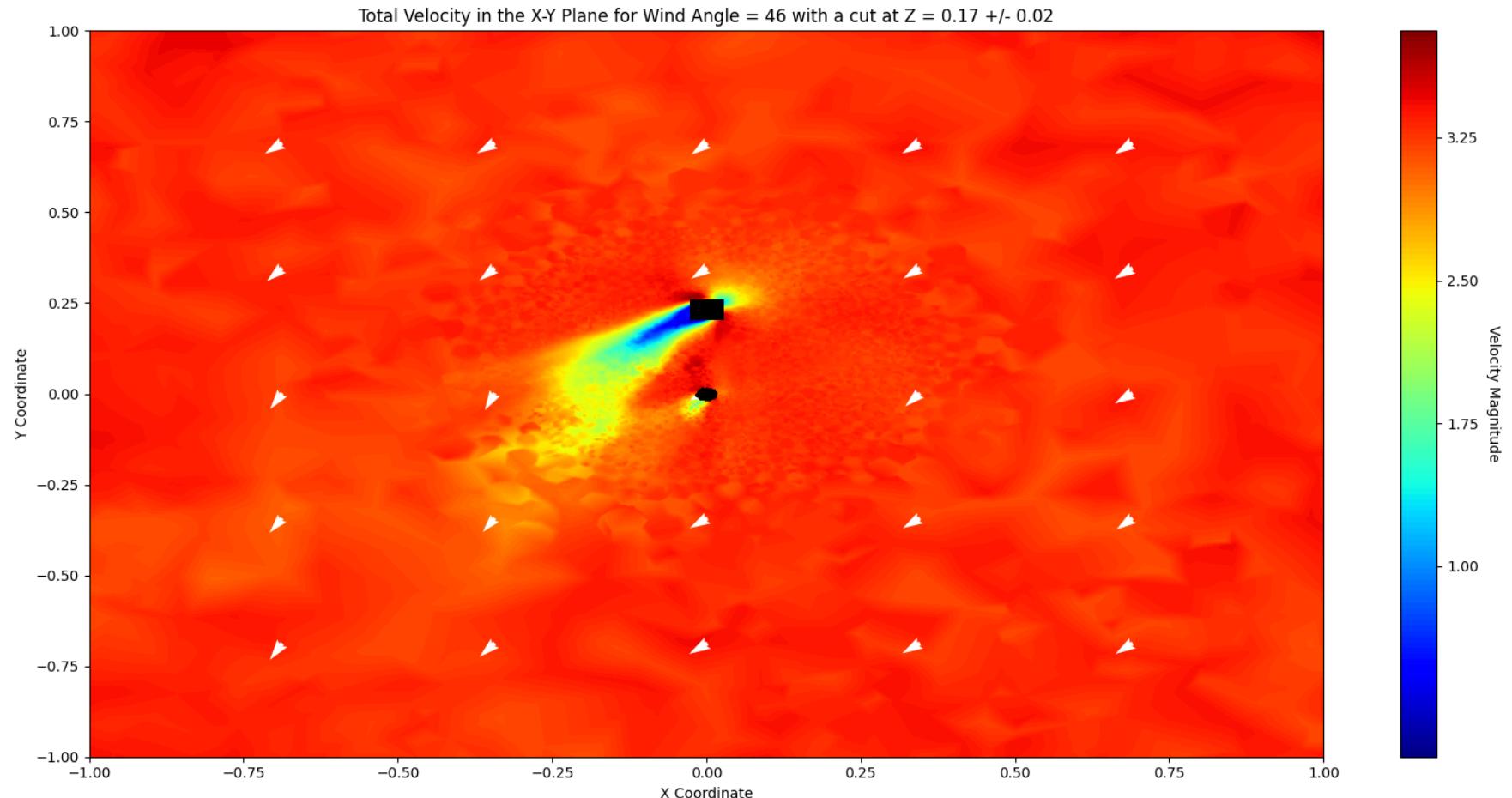
Data Plots – wind angle = 44



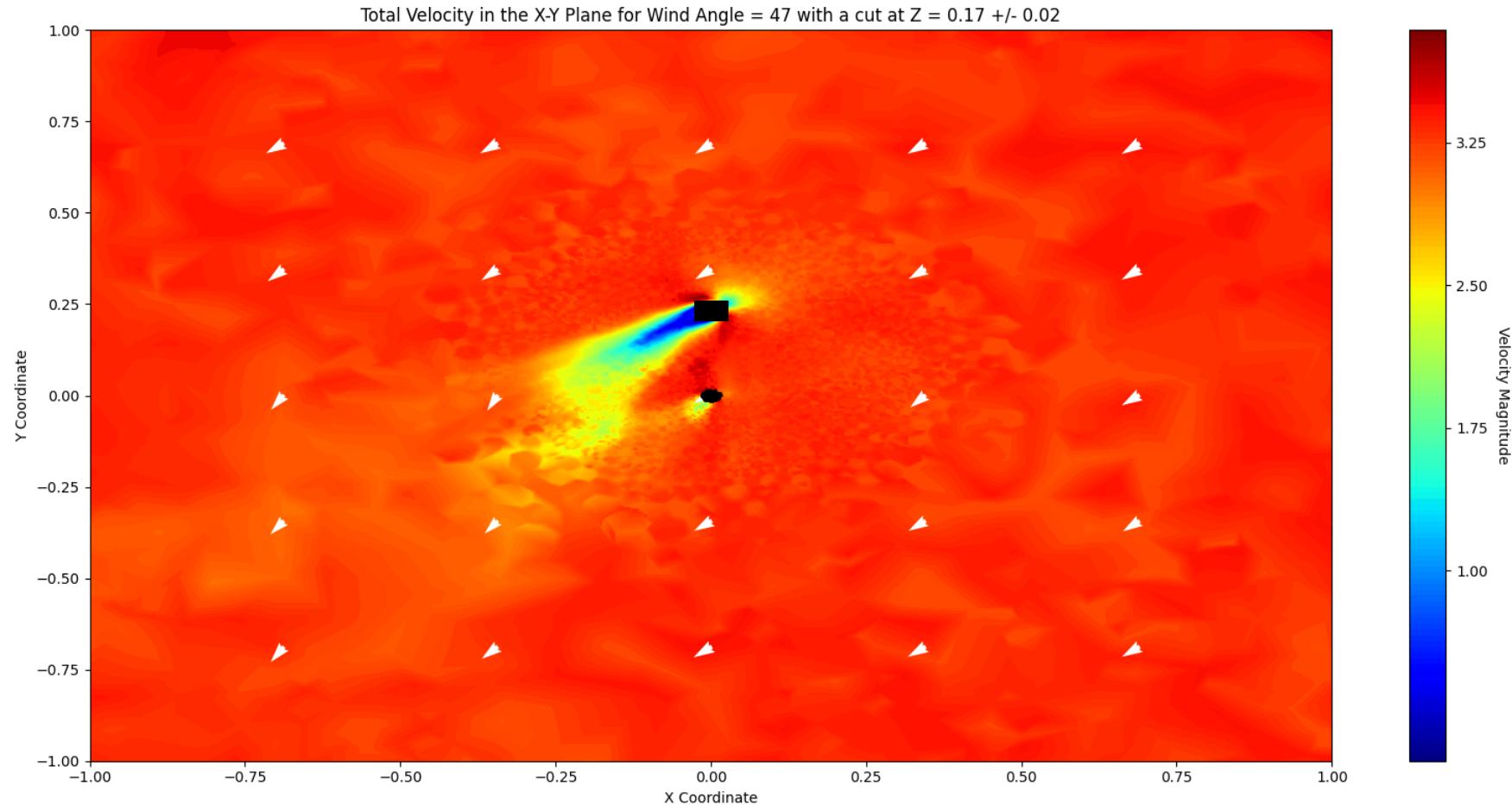
Data Plots – wind angle = 45



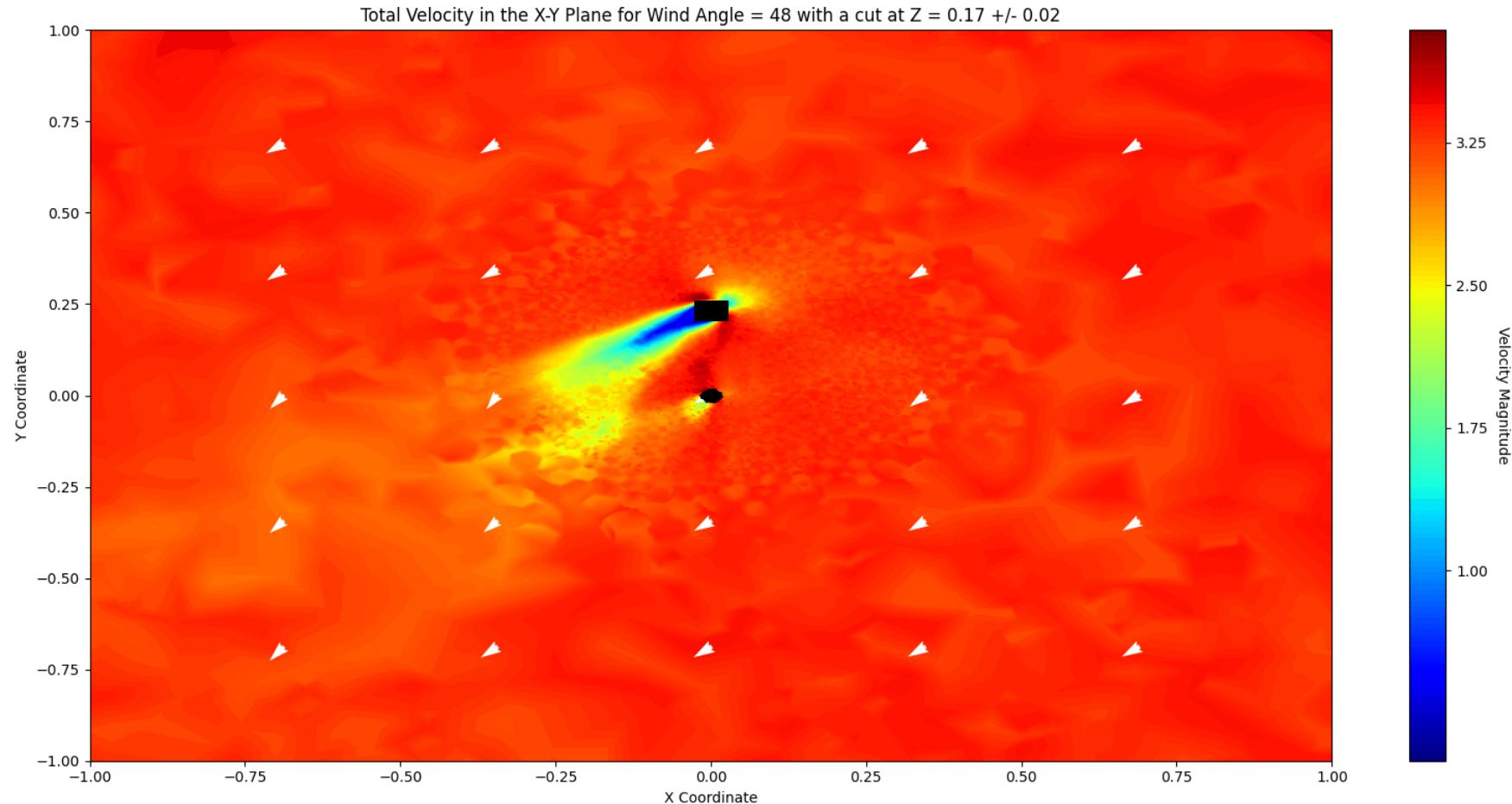
Data Plots – wind angle = 46



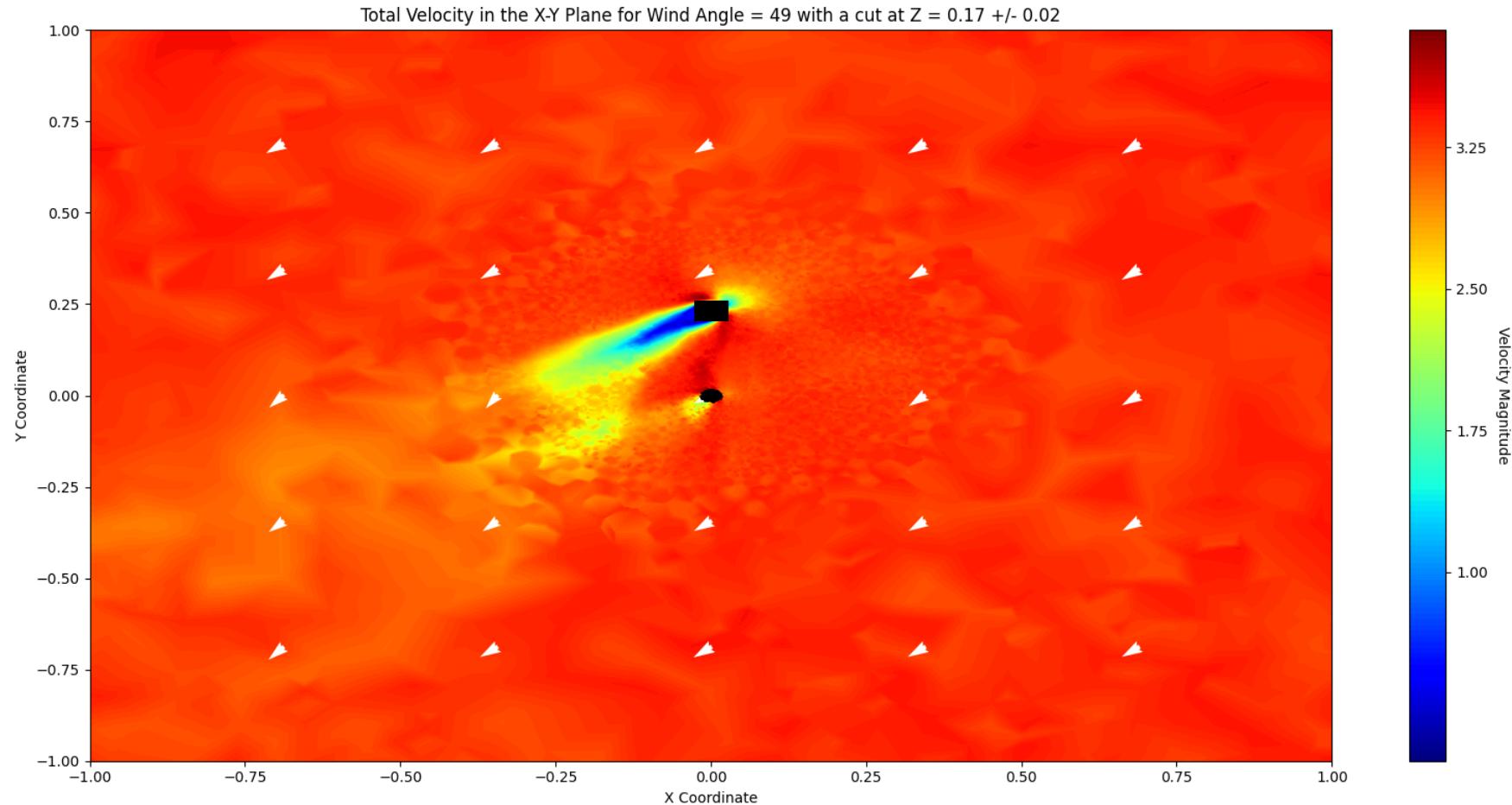
Data Plots – wind angle = 47



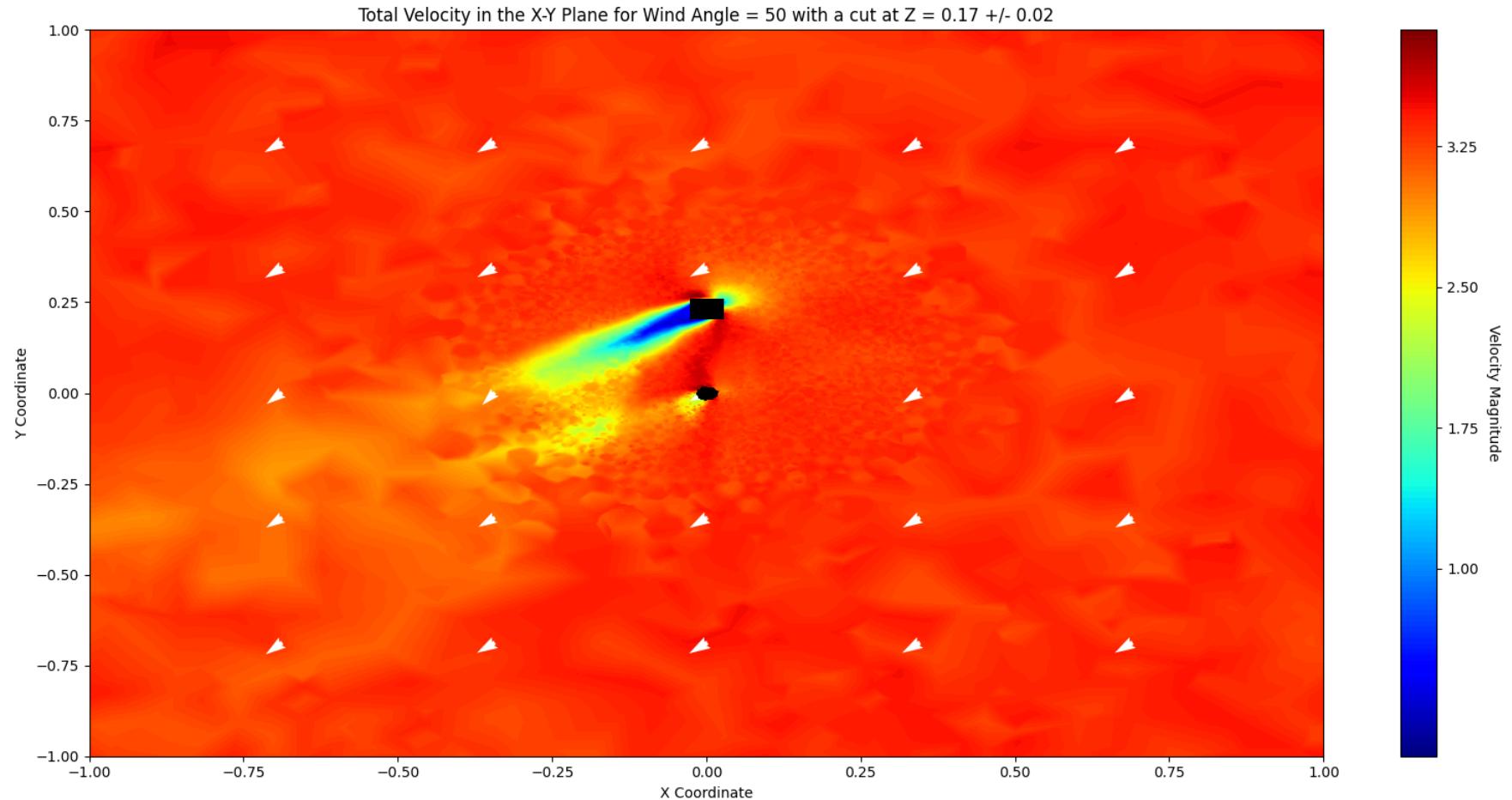
Data Plots – wind angle = 48



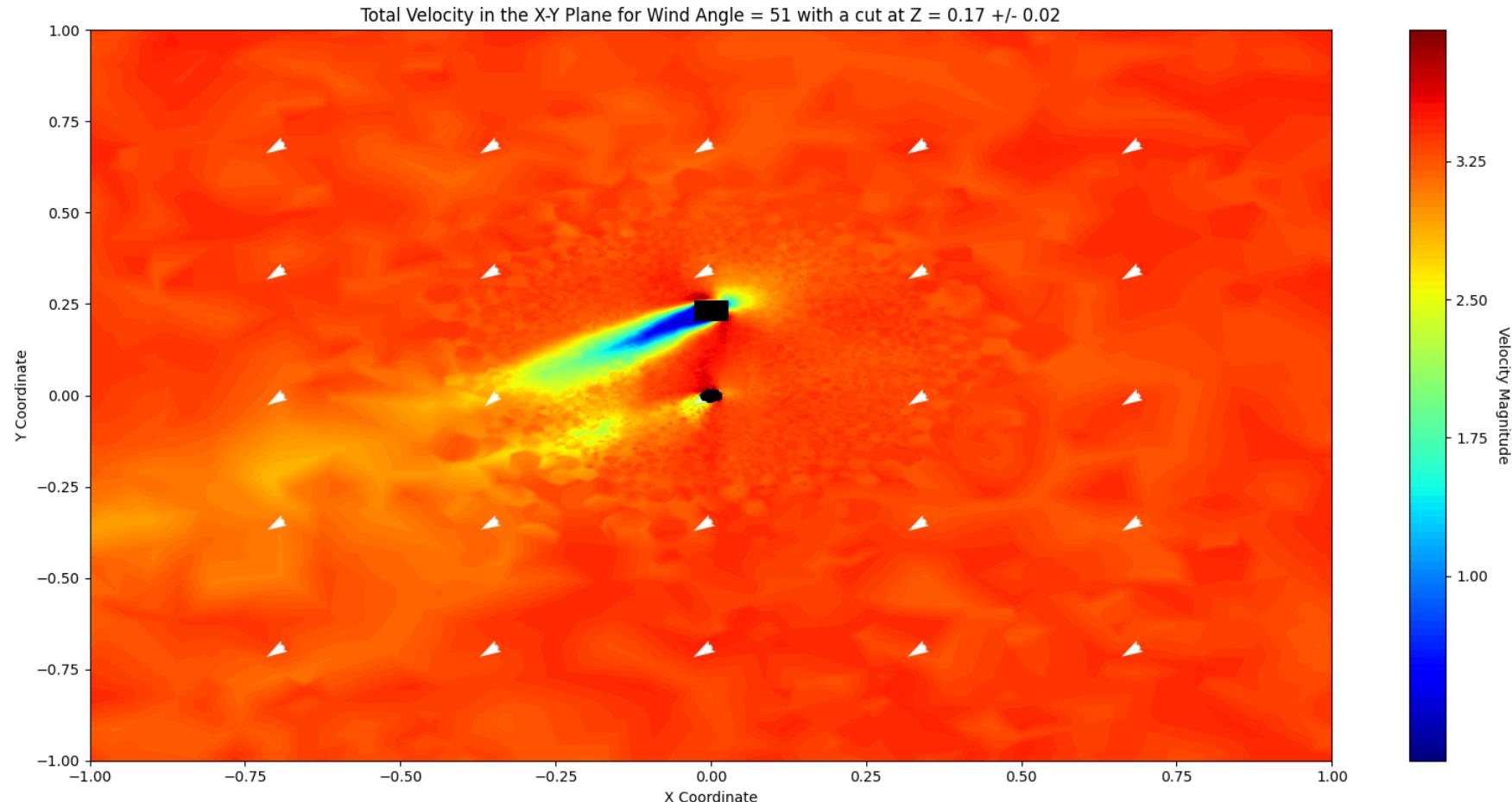
Data Plots – wind angle = 49



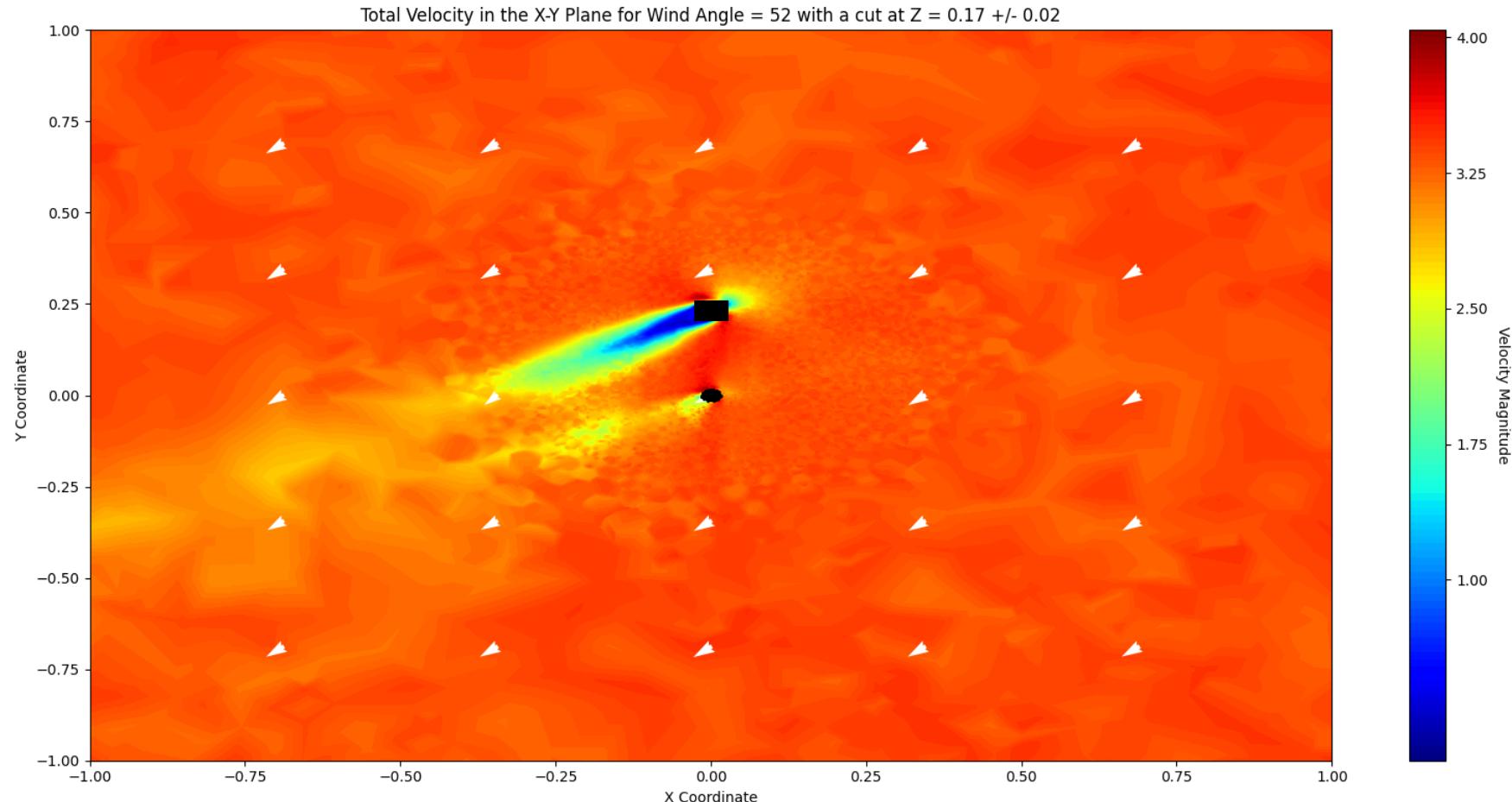
Data Plots – wind angle = 50



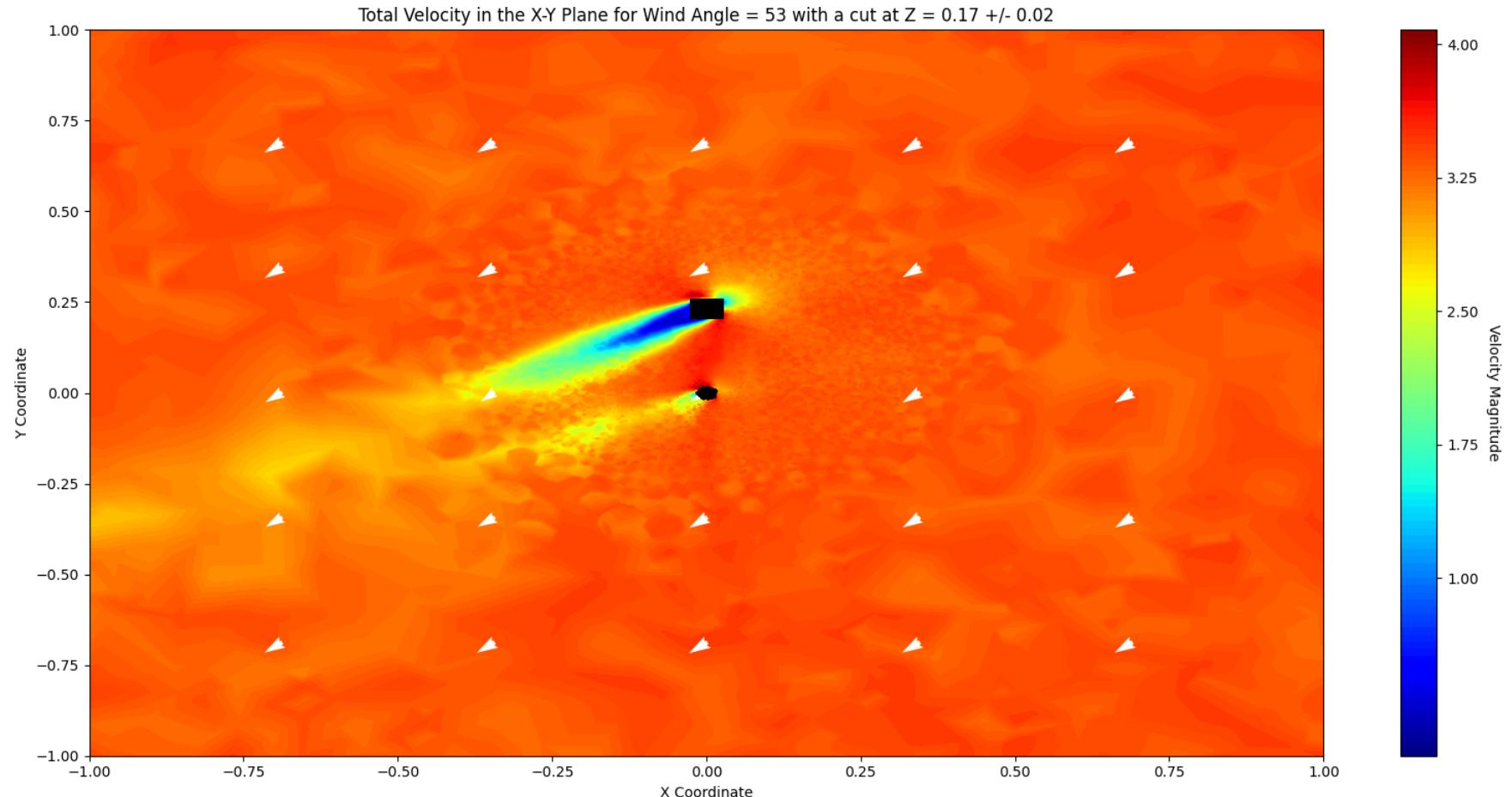
Data Plots – wind angle = 51



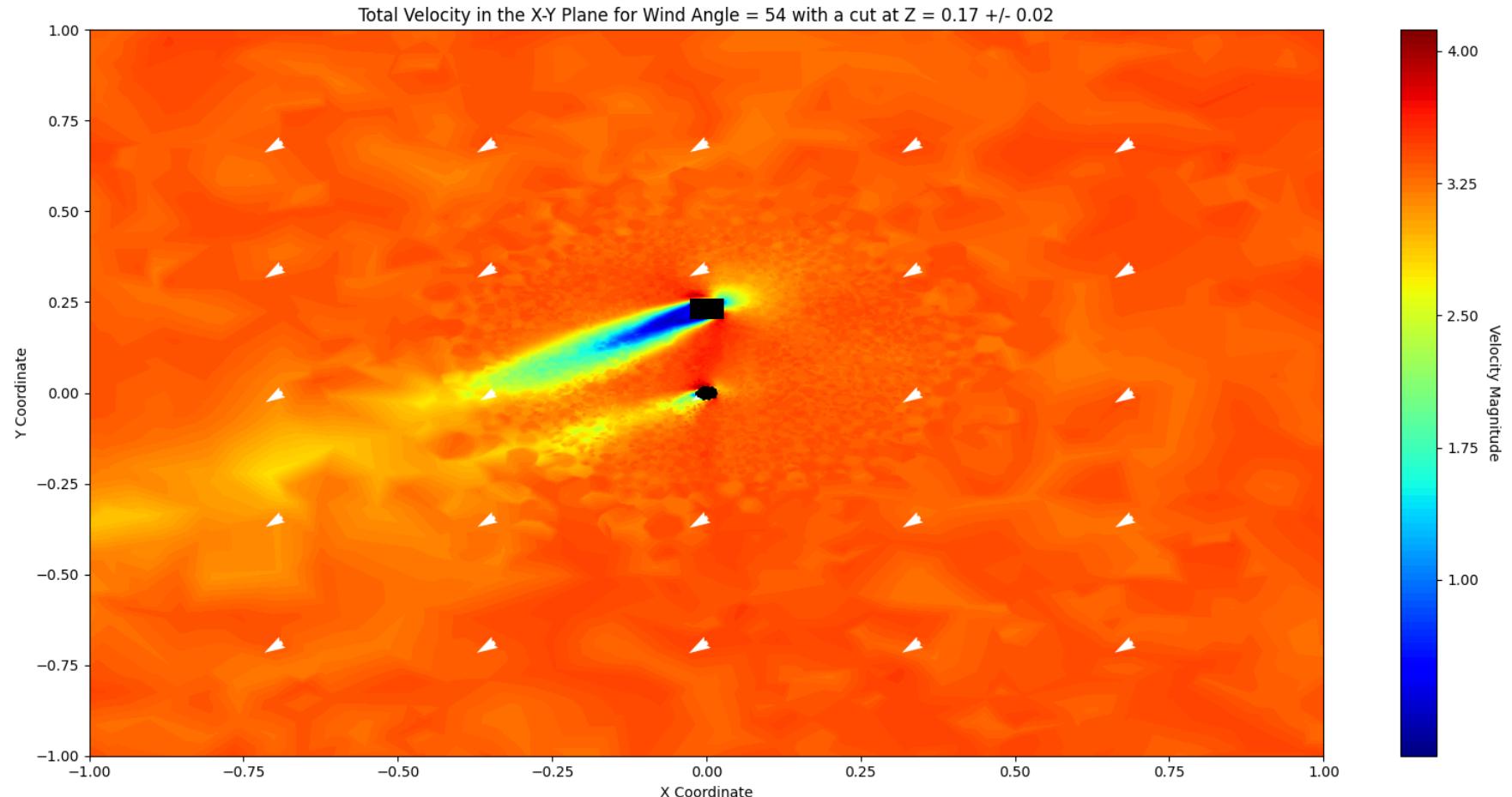
Data Plots – wind angle = 52



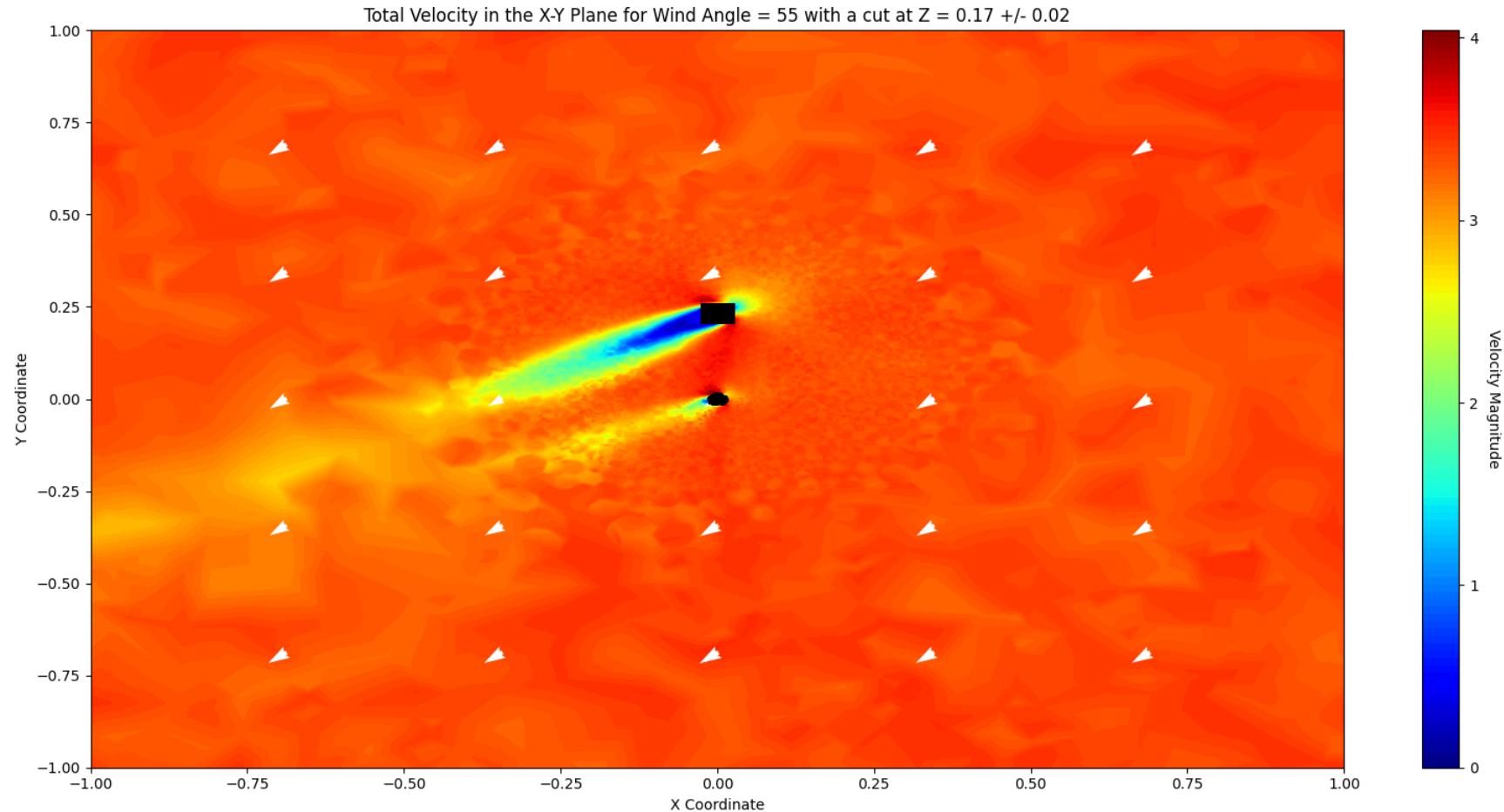
Data Plots – wind angle = 53



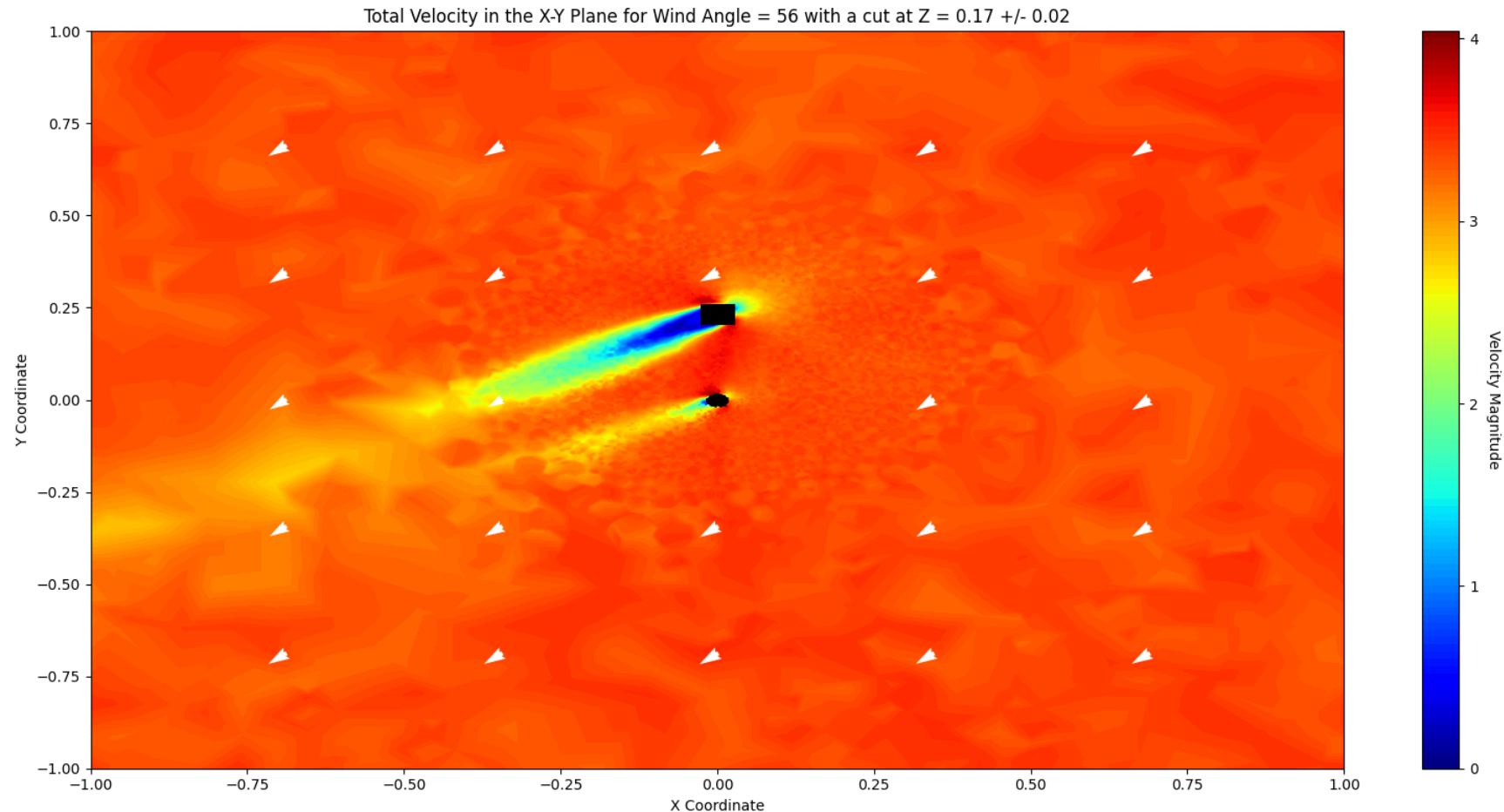
Data Plots – wind angle = 54



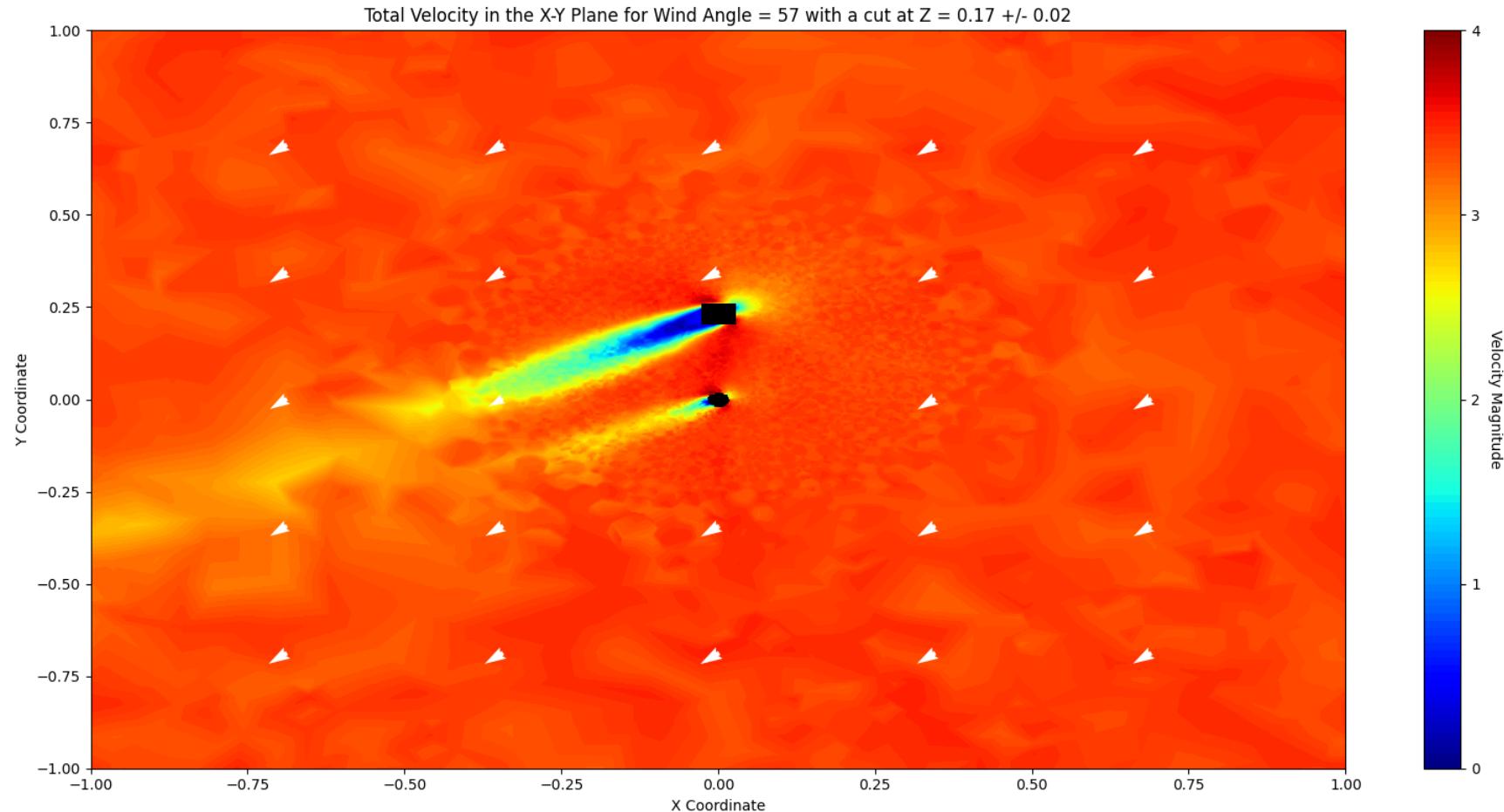
Data Plots – wind angle = 55



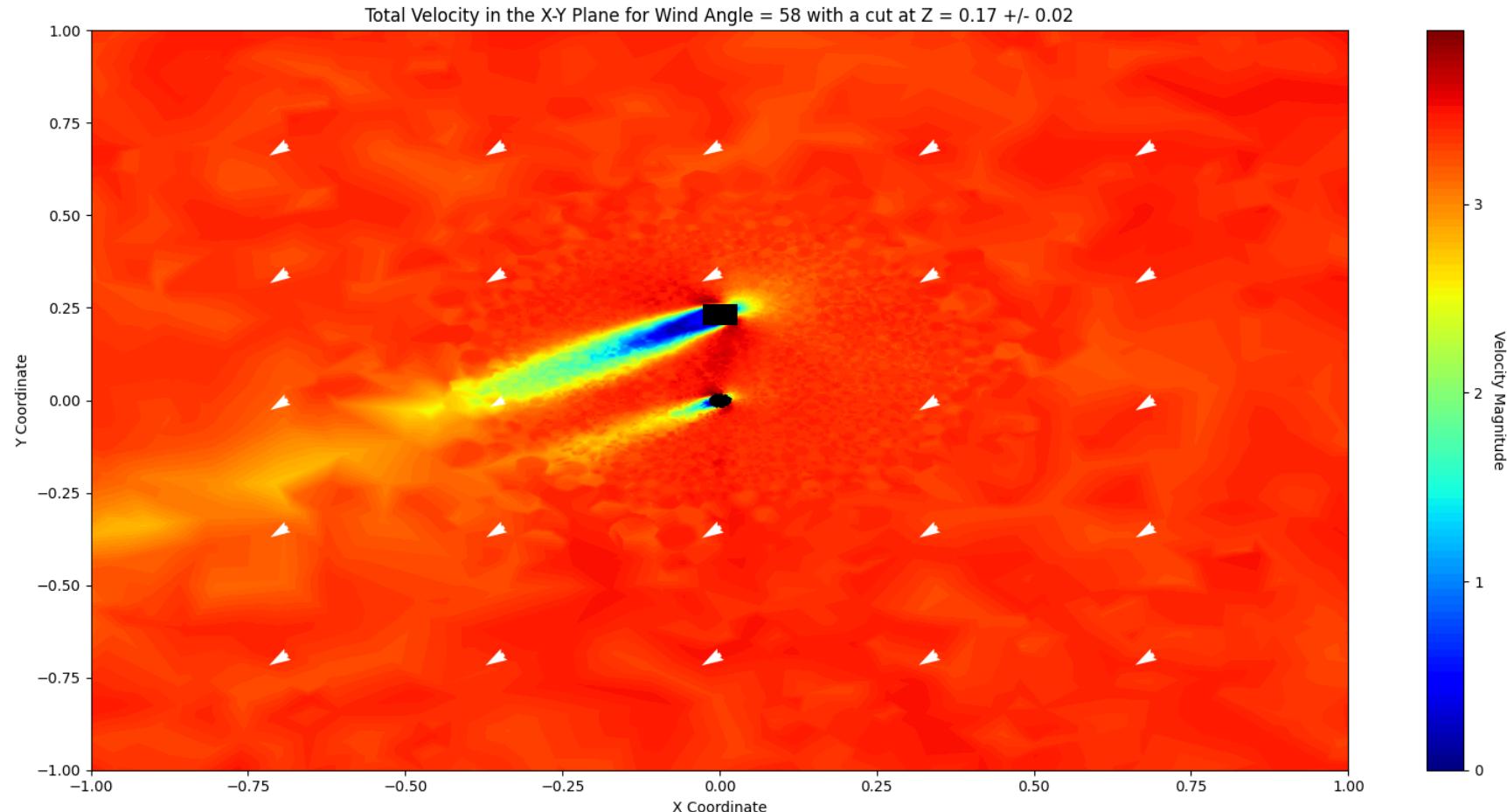
Data Plots – wind angle = 56



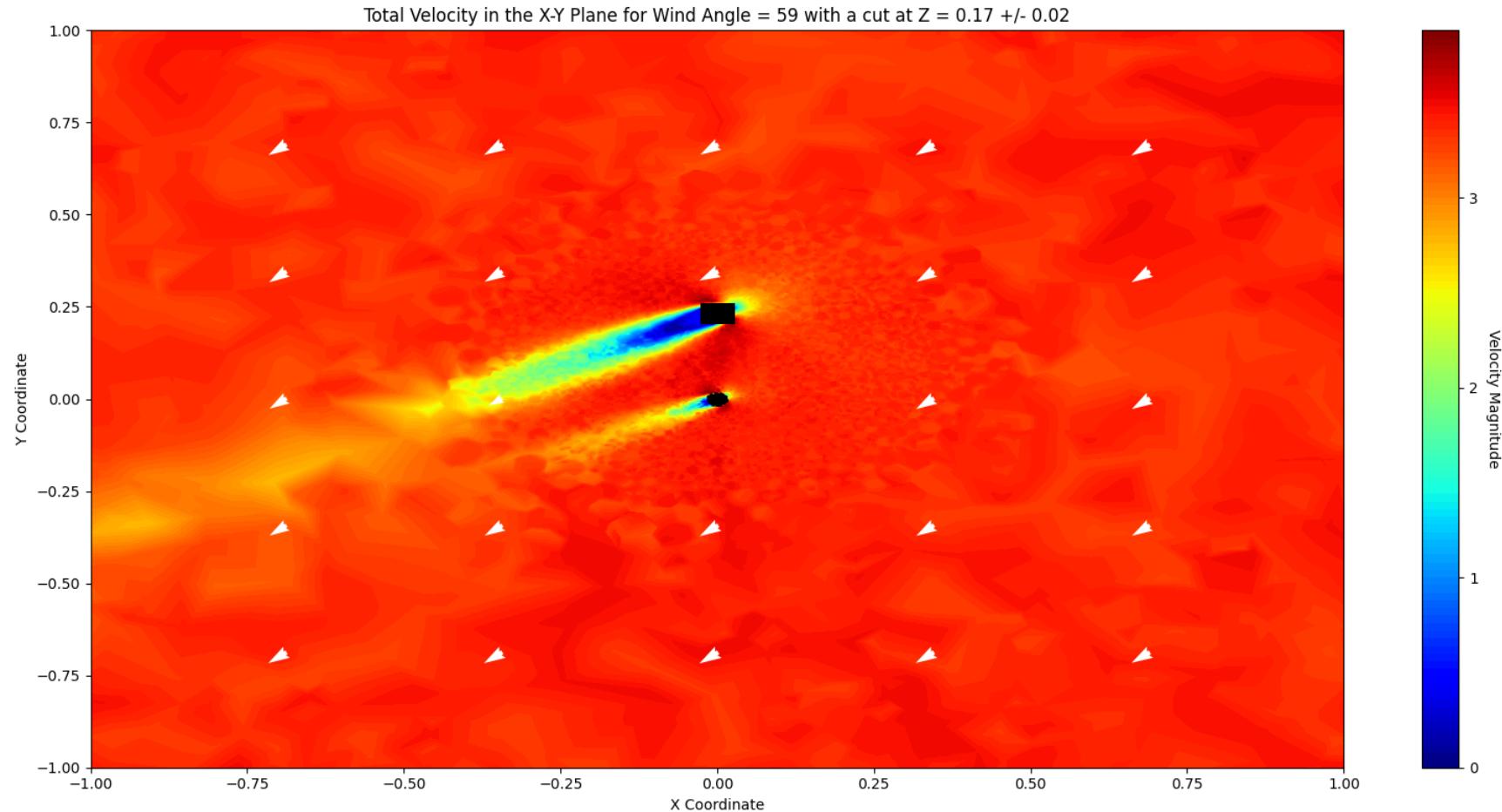
Data Plots – wind angle = 57



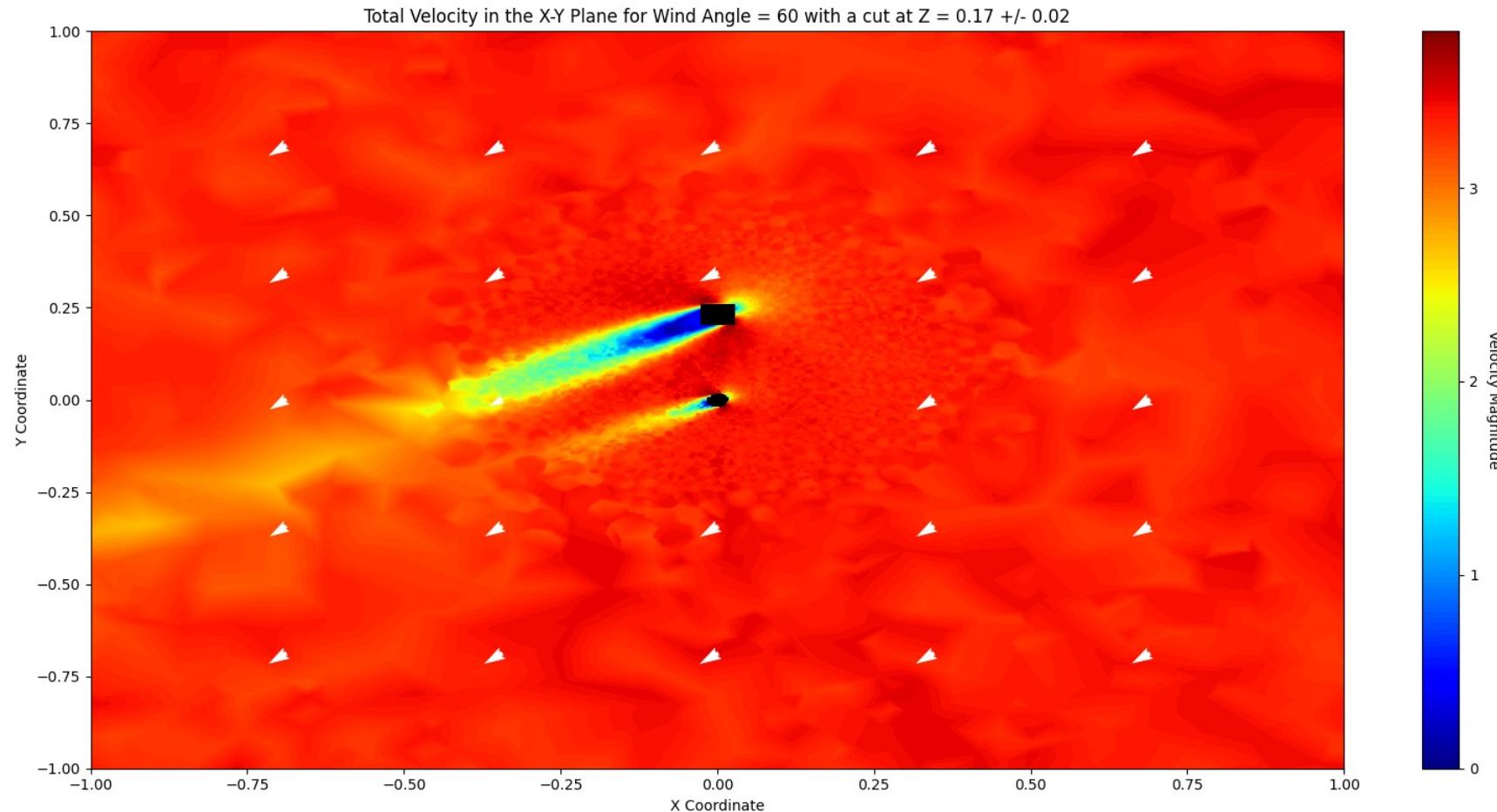
Data Plots – wind angle = 58



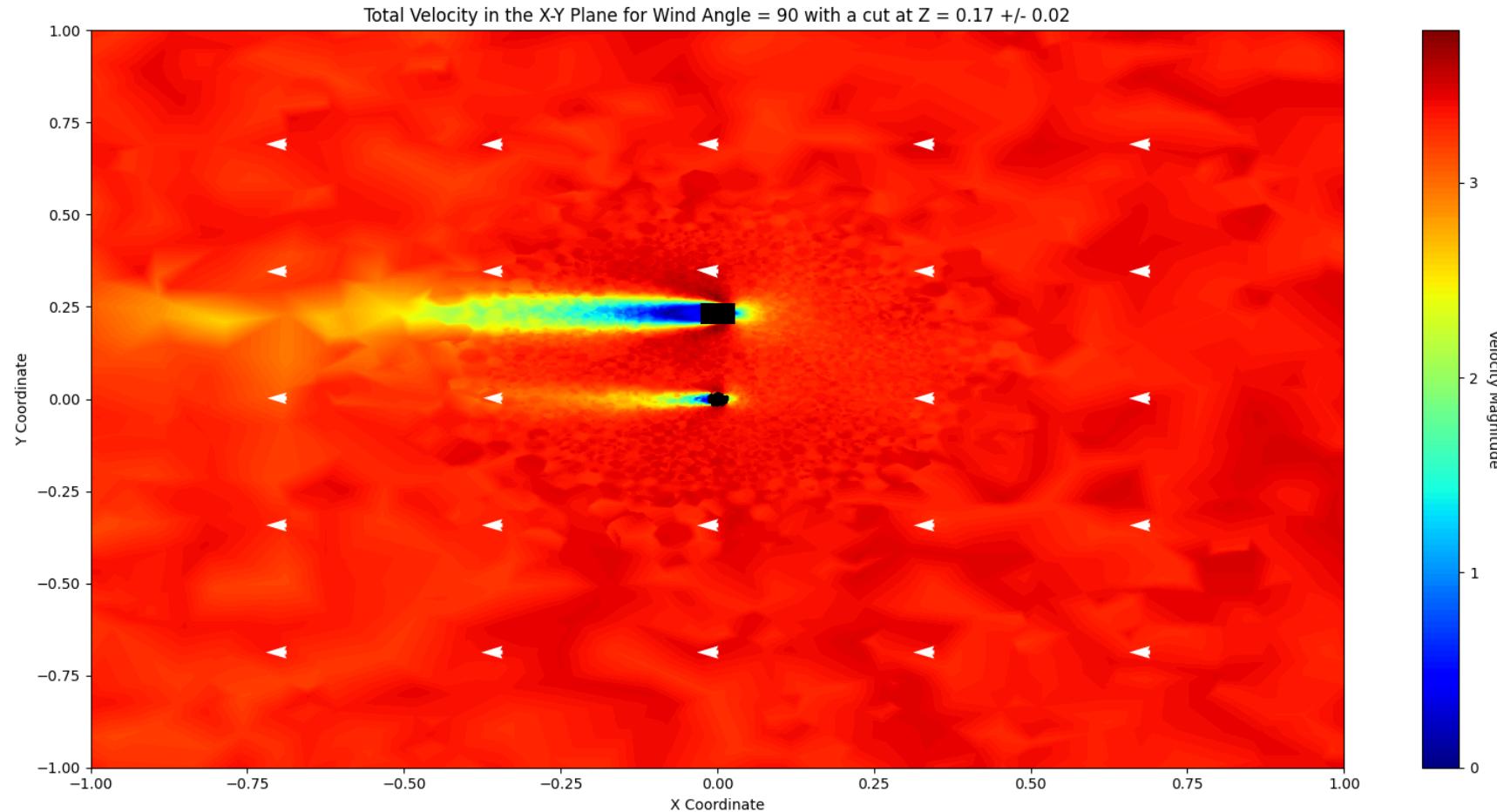
Data Plots – wind angle = 59



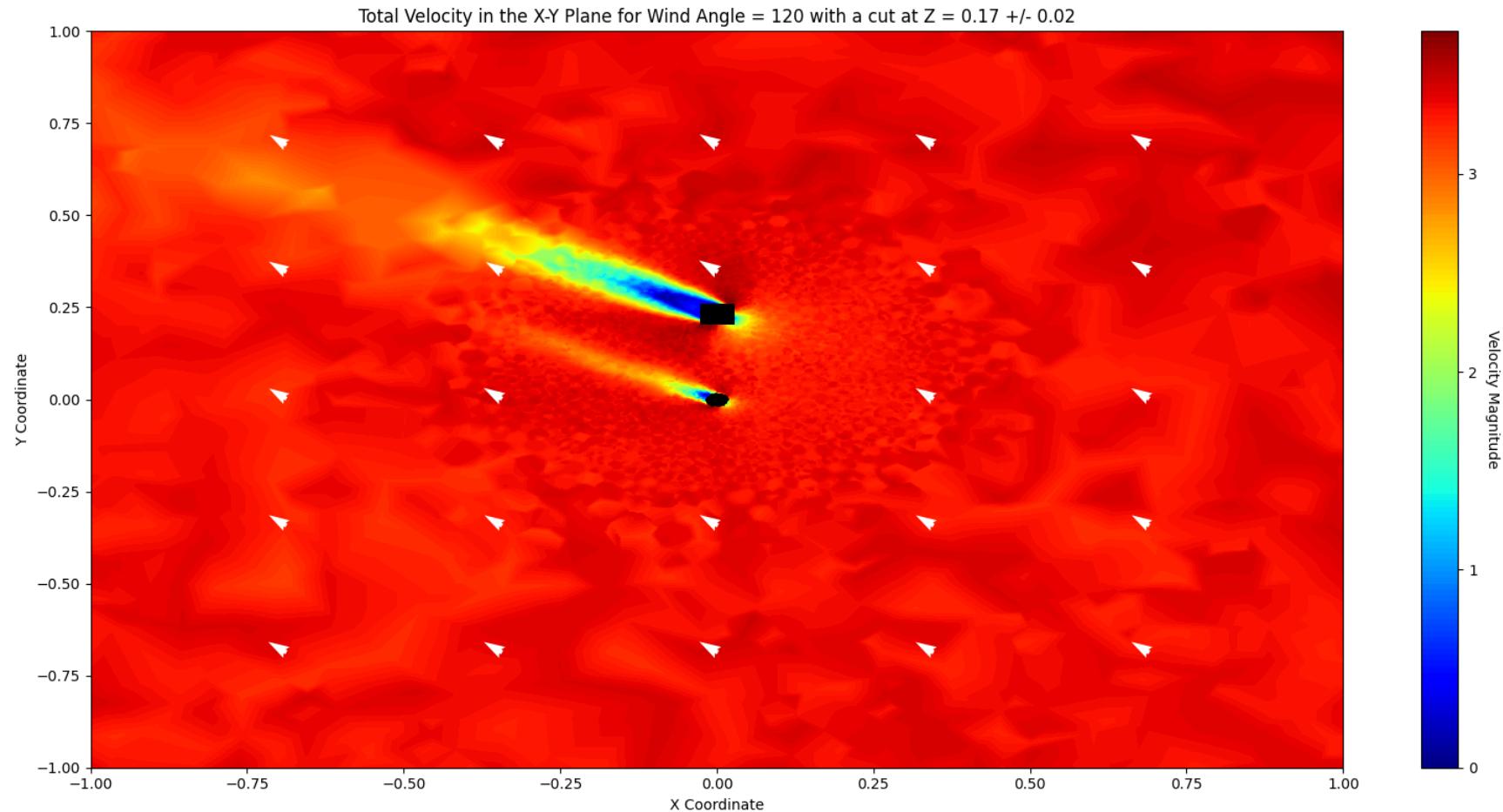
Data Plots – wind angle = 60



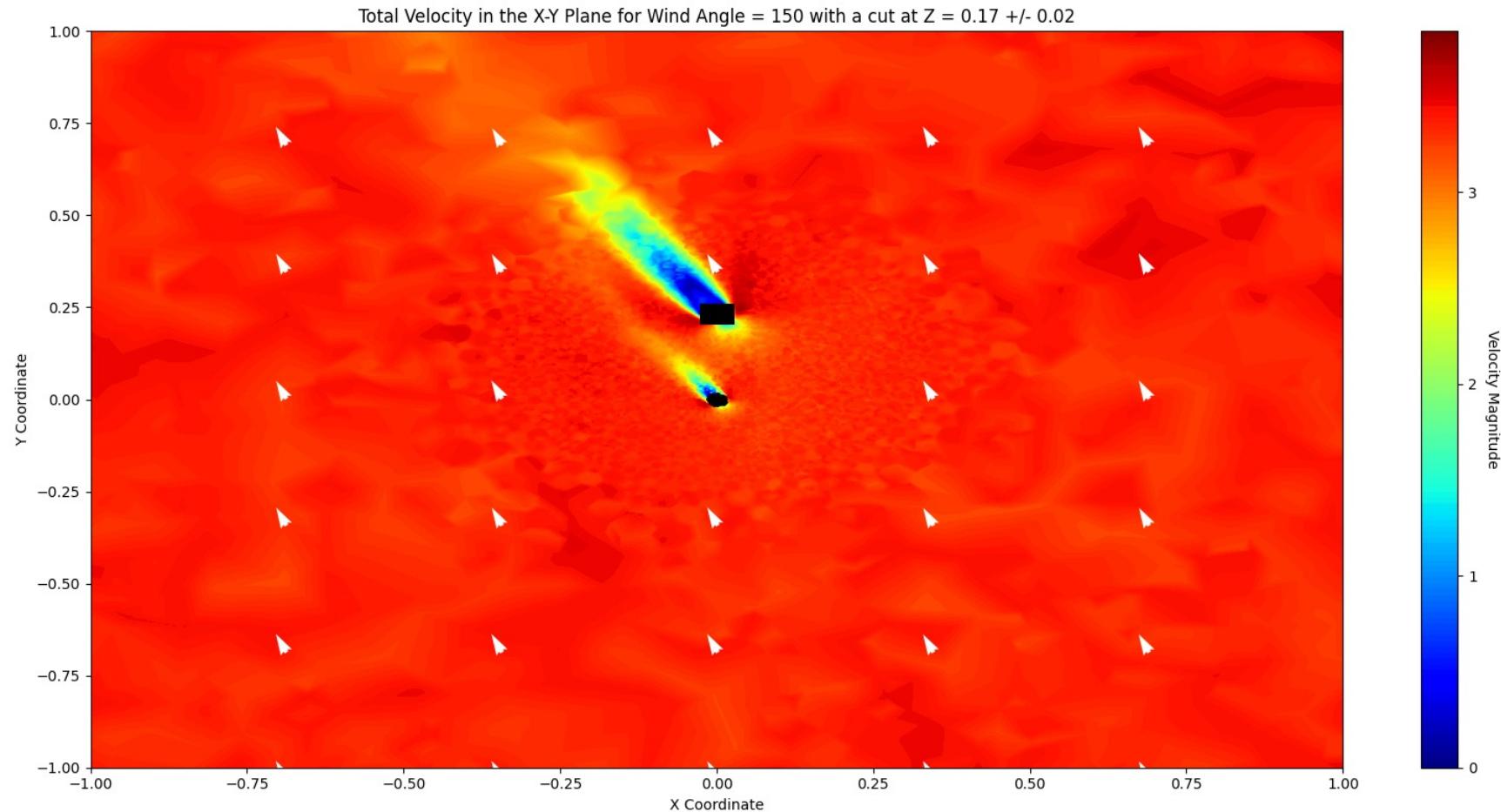
Data Plots – wind angle = 90



Data Plots – wind angle = 120



Data Plots – wind angle = 150



Data Plots – wind angle = 180

